Winter Run Life Cycle Model Overview

Workshop I

Morning

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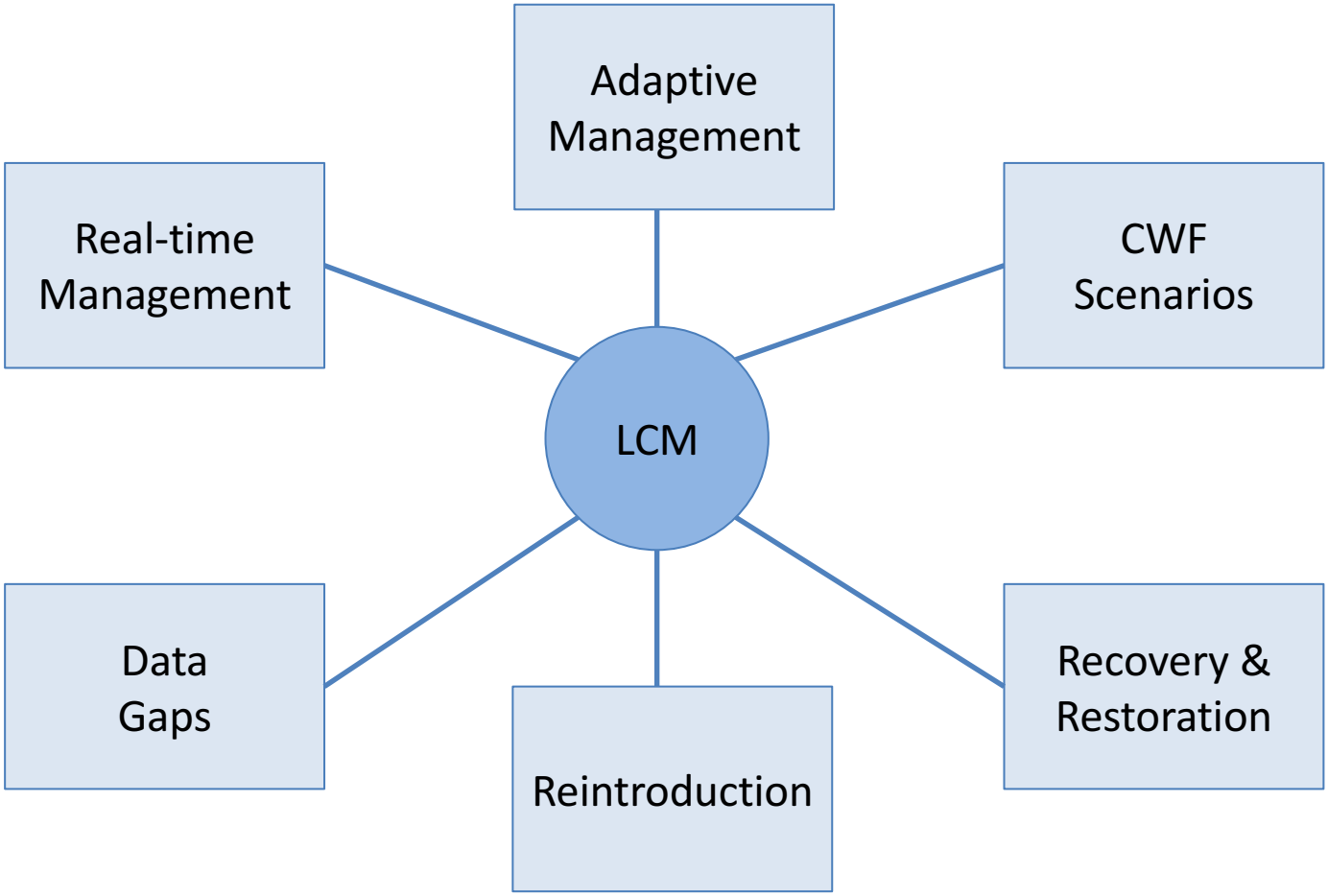
QEDα

Overall project goal

The main goal is to build a useful model

G.E.P. Box

What types of decisions do we want to address?



Rose et al. 2011 Review

"Critical aspects are: density-dependence, time-stepping, spatial grid, routing into and through the Delta, and ocean growth and survival"

"Consideration of life history variation and spatial distribution is needed"

Habitat diversity allows expression of different life history strategies in rearing and migration

Slide from Maya Friedman, UCSC & NOAA

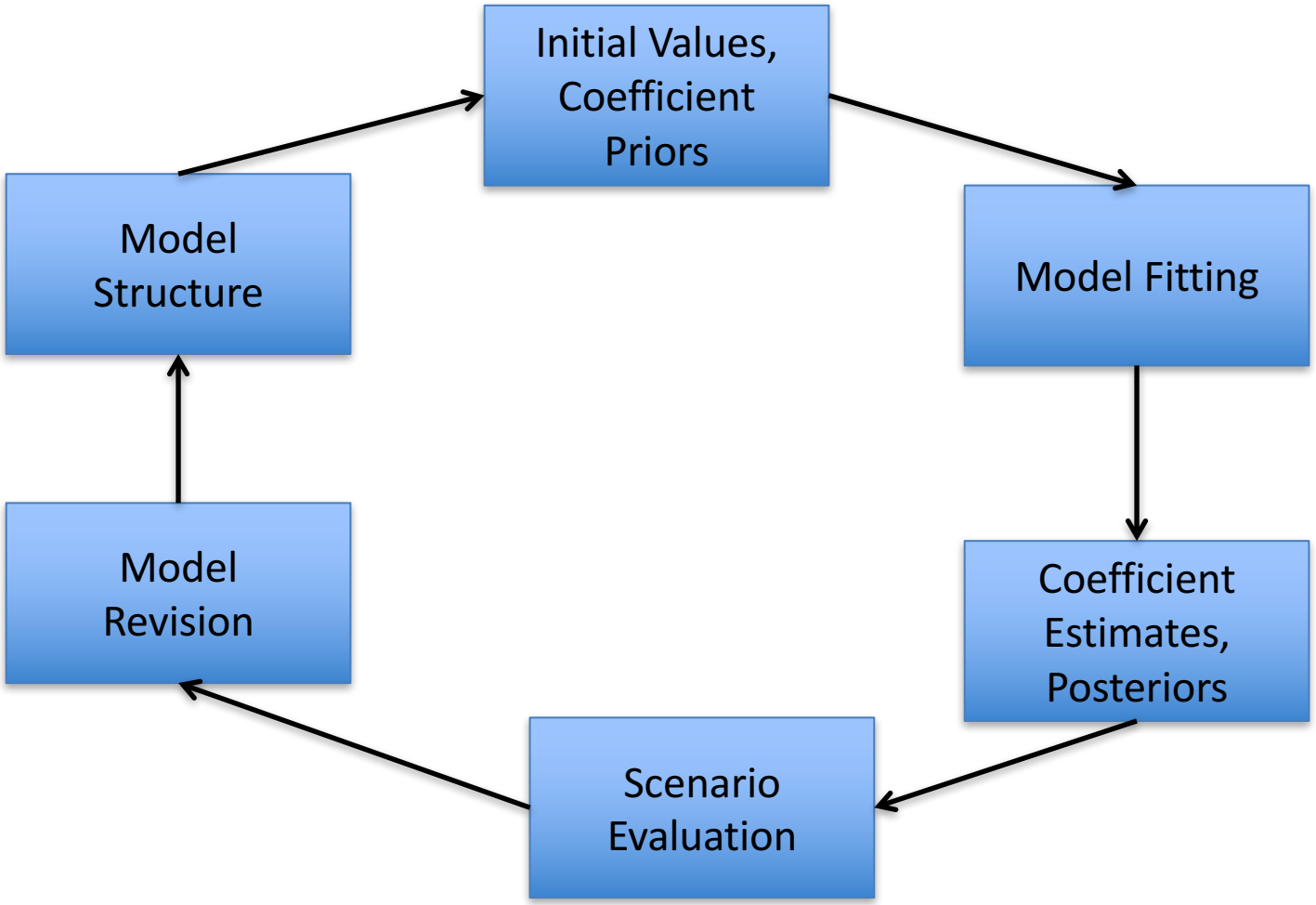
Useful Model Outputs

1. Specific - can provide specific relationships between population vital rates (e.g., survival or migration) and physical drivers of interest (e.g., flow or temperature)
2. Synoptic - can provide synoptic view of biological consequences of trade-offs
    1. Seasonally – e.g., water allocation in spring versus allocation in summer affects smolt production
    2. Annually – e.g., allocation strategy across different year types affects adult abundance

WINTER-RUN LIFE CYCLE MODEL

Modeling Steps

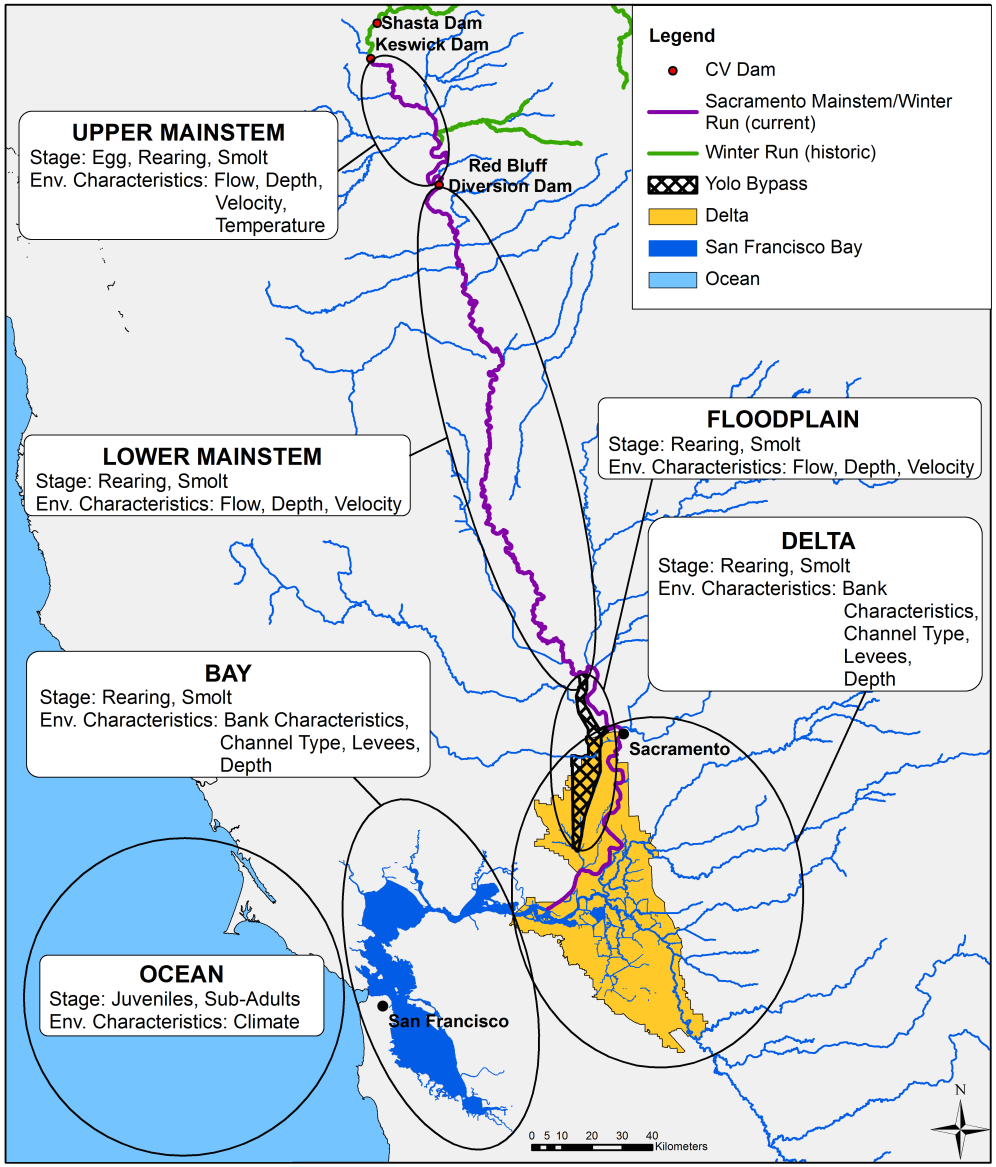
(Currently on Version 1.4.2)



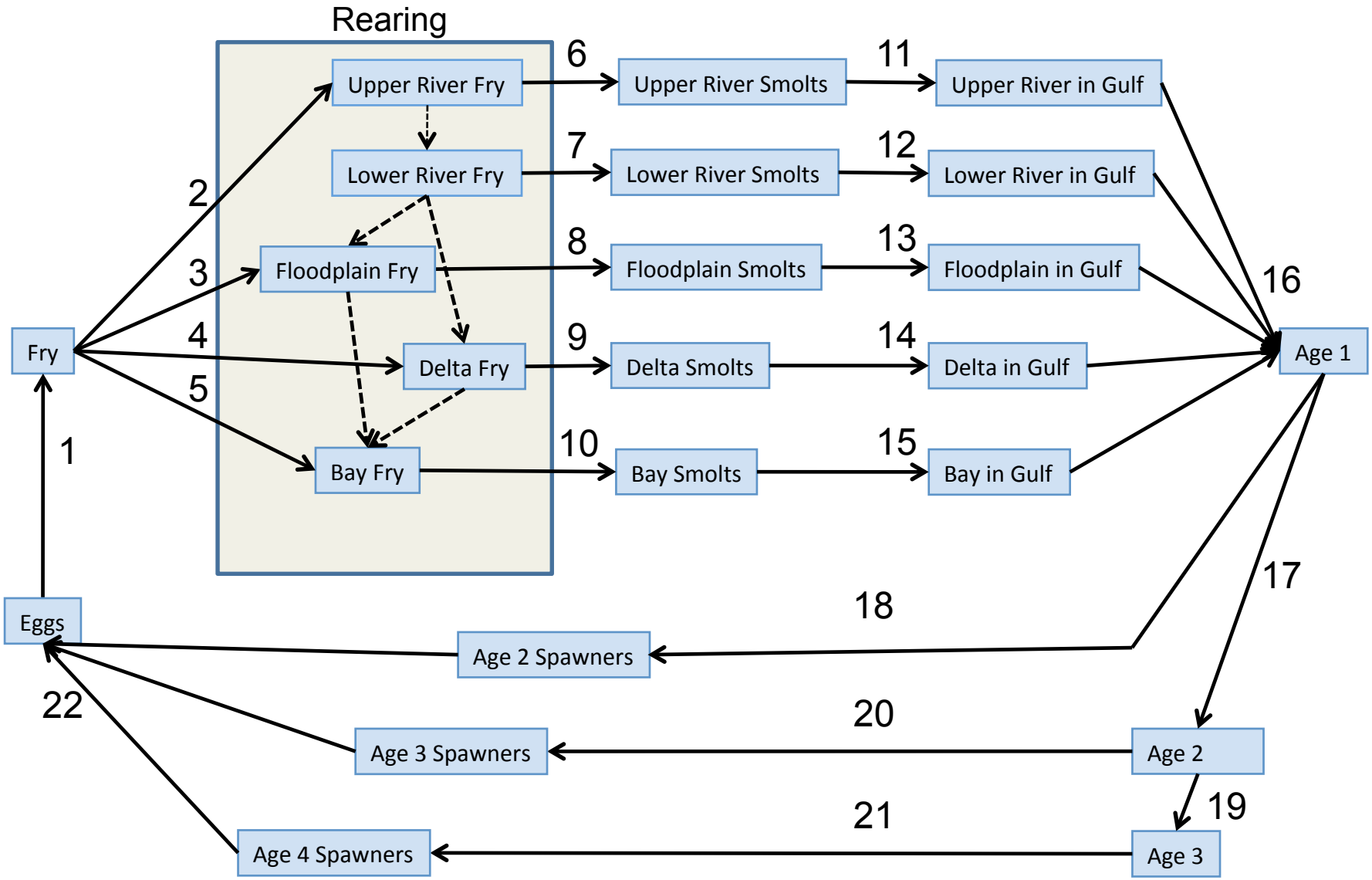
Timeline of WRLCM development

- 2012
  - Workshops – feedback on model structure, data availability, biological mechanisms
  - Evaluate Shiraz – reject Shiraz
  - Build prototype models in SLAM – reject SLAM
- 2013
  - Build initial models in R
  - Revise models in R
  - More workshops for biological review and data discussion
- 2014
  - Finalize Version 1.0 – a proof of concept
  - Use V 1.0 to evaluate climate scenarios
- 2015
  - Revise model to V 1.2
  - Center for Independent Experts model review: 1) split River habitat and 2) add process noise to make state-space
- 2016
  - More revisions, add annual random effects
  - Model 'fixed' for evaluating actions
  - Scientific Panel Review of WRLCM for Cal Water Fix

Spatial Structure

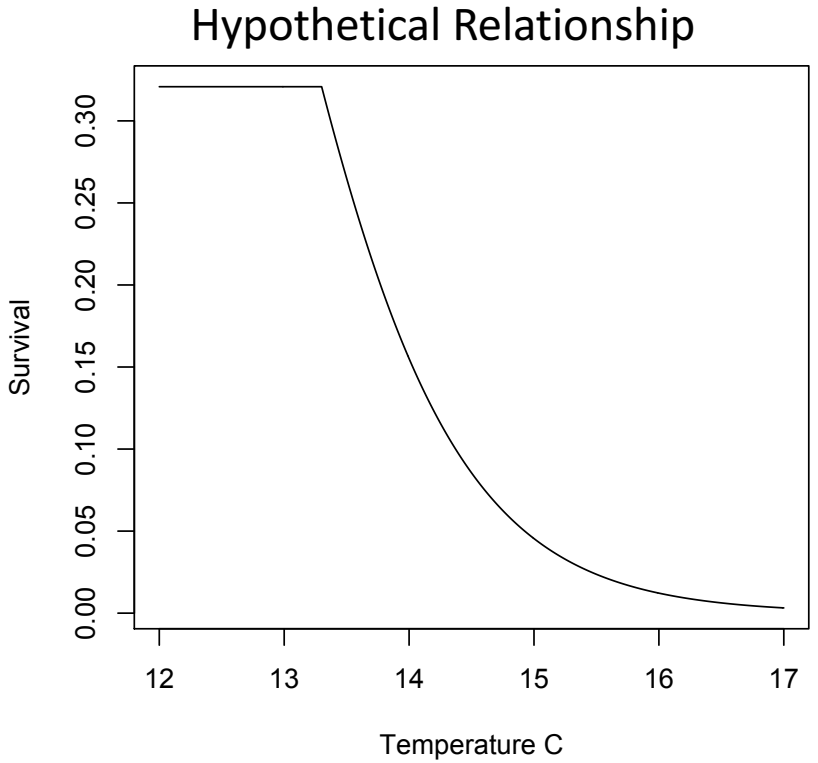


WRLCM Diagram



Change-point model for thermally induced egg mortality

- Below a temperature threshold (*t.crit*) survival is stable
- Above *t.crit*, survival can decrease via a logistic regression

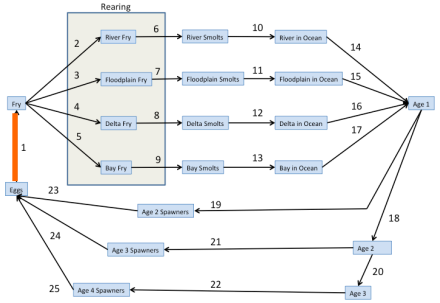


Survival from Egg to Fry stage

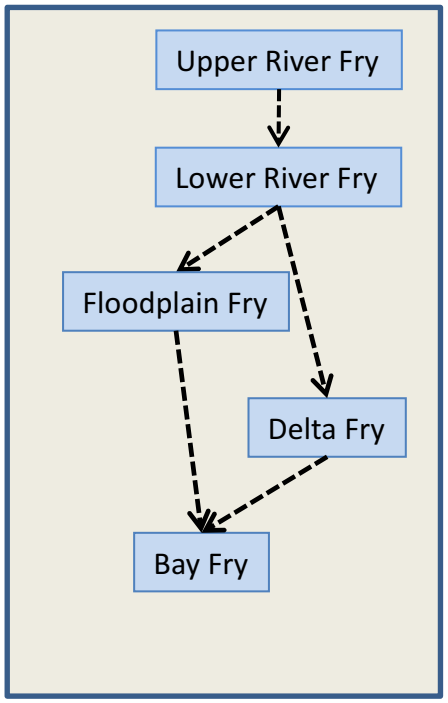
$$Fry_{m+2} = Eggs_m * S_{eggs,\,m}$$

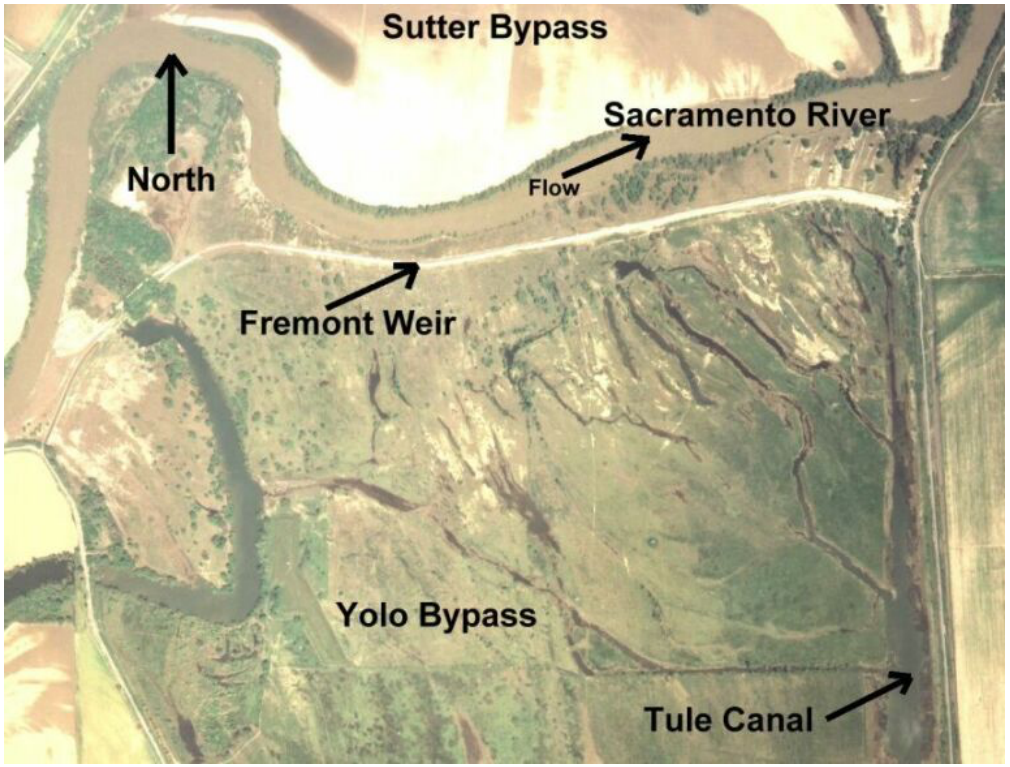
$$logit(S_{eggs,m}) = \begin{cases} B0_1, & TEMP \leq t.crit \\ B0_1 + B1_1(TEMP_m - t.crit), & TEMP > t.crit \end{cases}$$

$TEMP_m$ = 3 month average temperature post spawning temperature threshold



Spatial Linkages

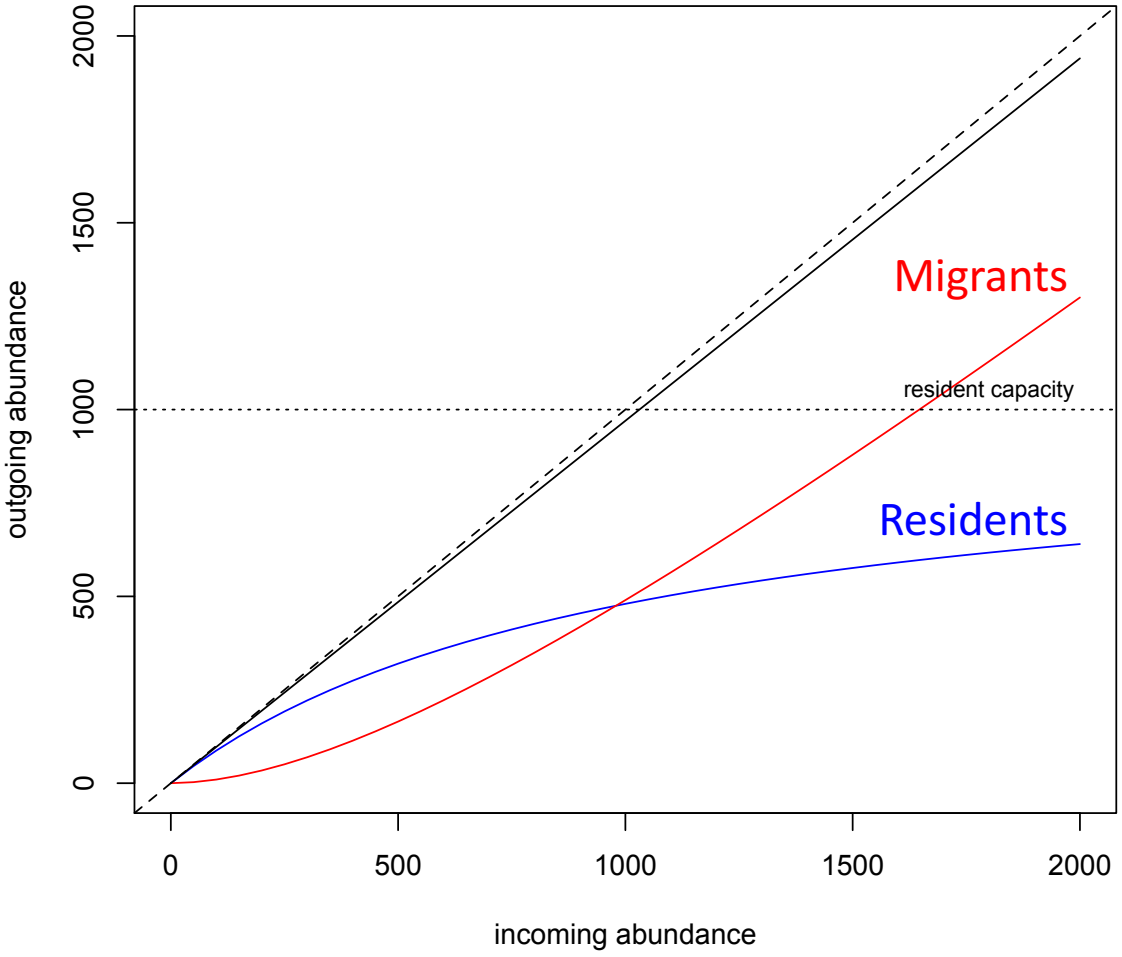




Credit: T. Endreny SUNY

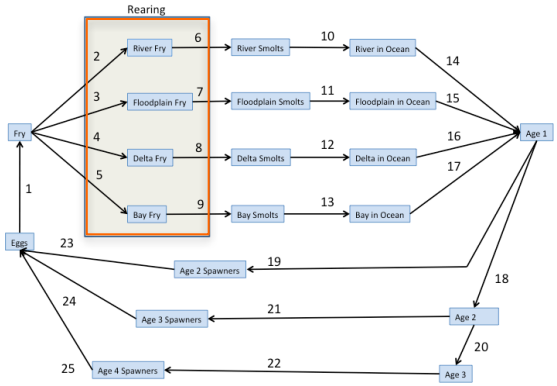
Fry can enter into Floodplain habitat only when there is flow into Yolo Bypass

Fry Rearing
Movement Function



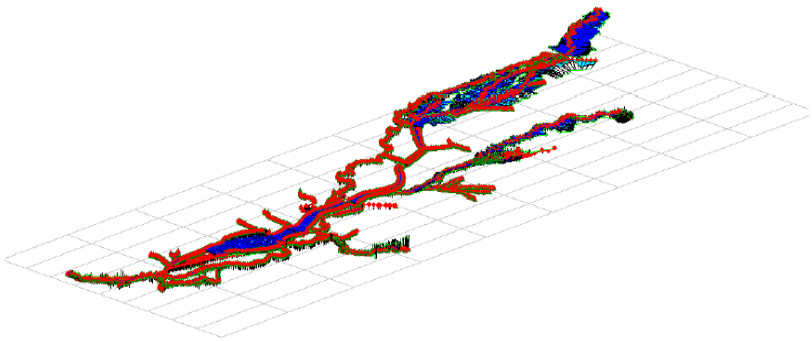
$$\text{Resident}_{h,m} = \frac{S_{h,m}(1-mig_{h,m})N_{h,m}}{1+S_{h,m}(1-mig_{h,m})N_{h,m}/K_{h,m}}$$

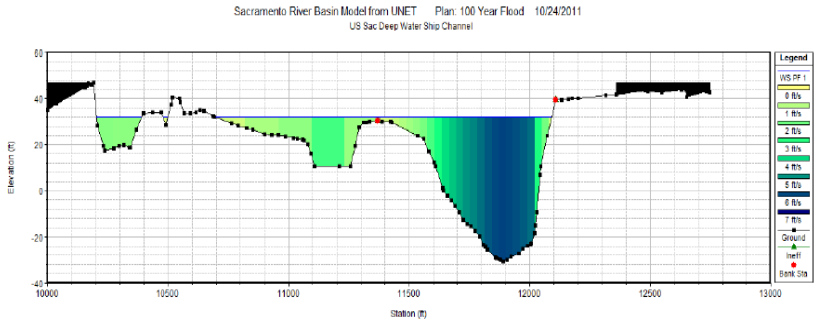
$$\text{Migrant}_{h,m} = S_{h,m}N_{h,m} - \text{Resident}_{h,m}$$



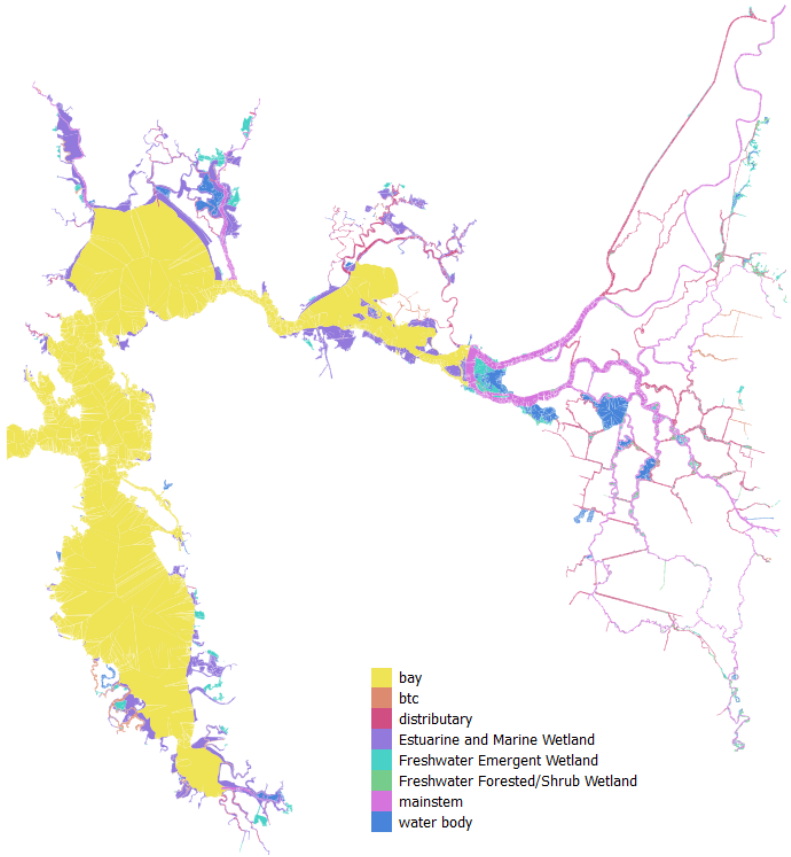
Habitat capacity

HEC-RAS modeling for obtaining preference categories in River habitats





GIS modeling for obtaining preference categories in Delta and Bay habitats



Smoltification

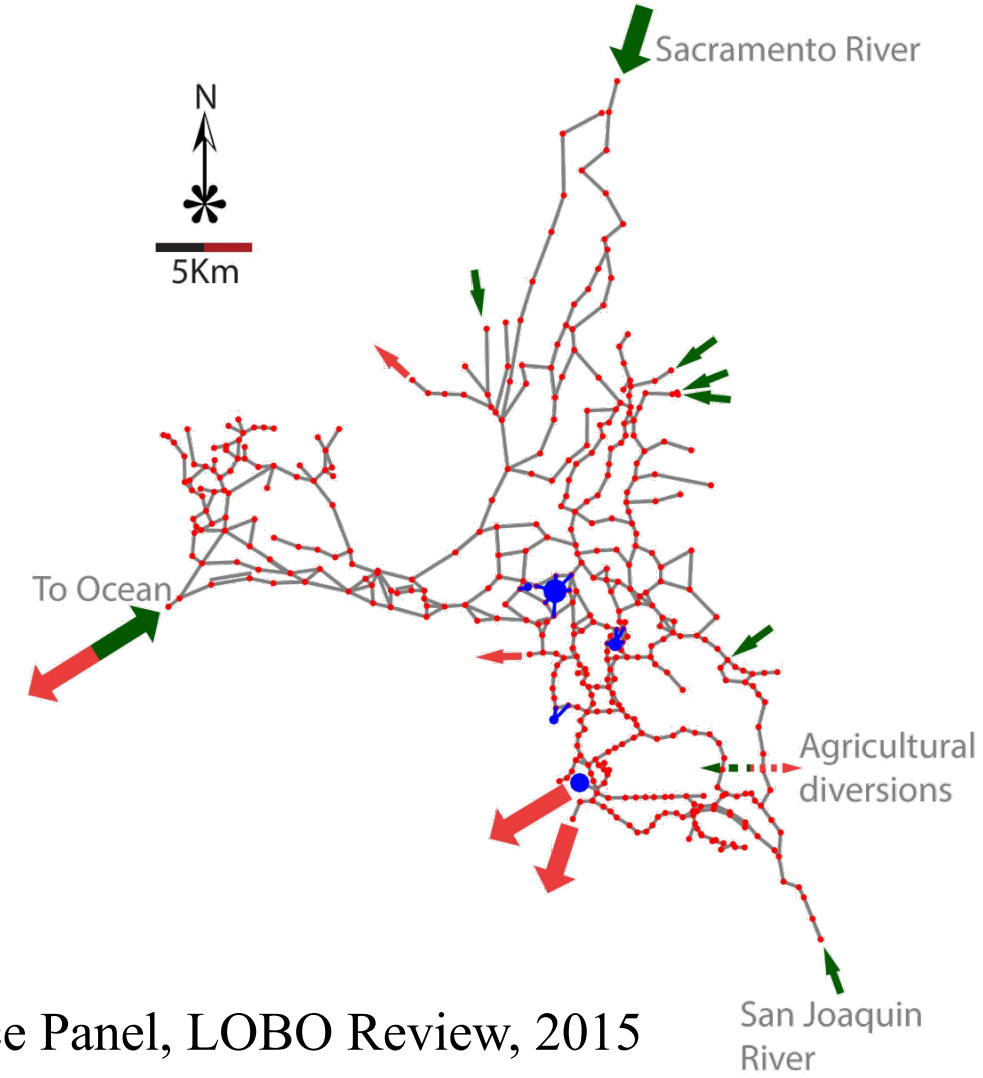
Probability of smolting P_{smolt} is modeled as a proportion ordered logistic regression

$$\text{logit}(P_{smolt,\,m}) = Z_k$$

where $-\infty < Z_1 < Z_2 \ldots < Z_k < \infty$ are the monthly rates of smoltification based on photoperiod (k = 1, …, 7 encompassing January to July).

Credit: salmonguy.org

Smolt survival using Enhanced Particle Tracking Model (ePTM)



Source: Delta Science Panel, LOBO Review, 2015

Reaching the Ocean

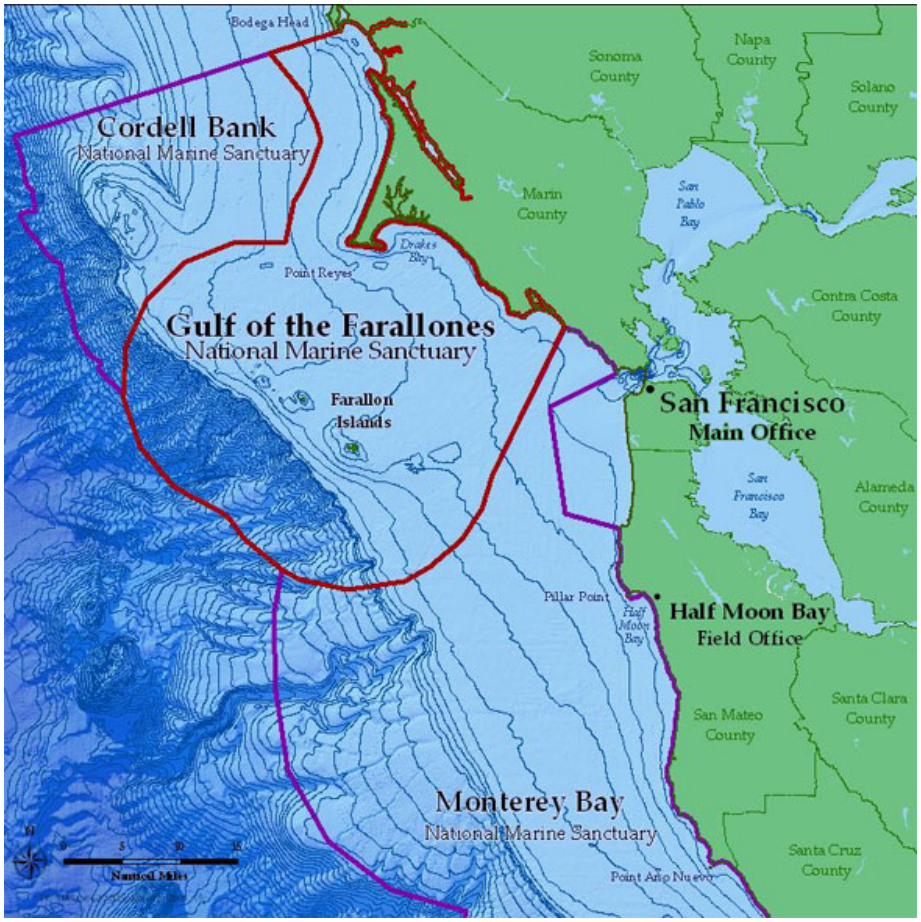
Gulf of Farallones stage –

$$Gulf_{h,m} = Smolt_{h,m-1} S_{smolt,h,m-1} \exp(\varepsilon_y)$$

$$S_{smolt,h,m-1} = f(\text{ePTM}_{h,m-1})$$

$$\varepsilon_y \sim \text{N}(0, \sigma_\varepsilon^2)$$

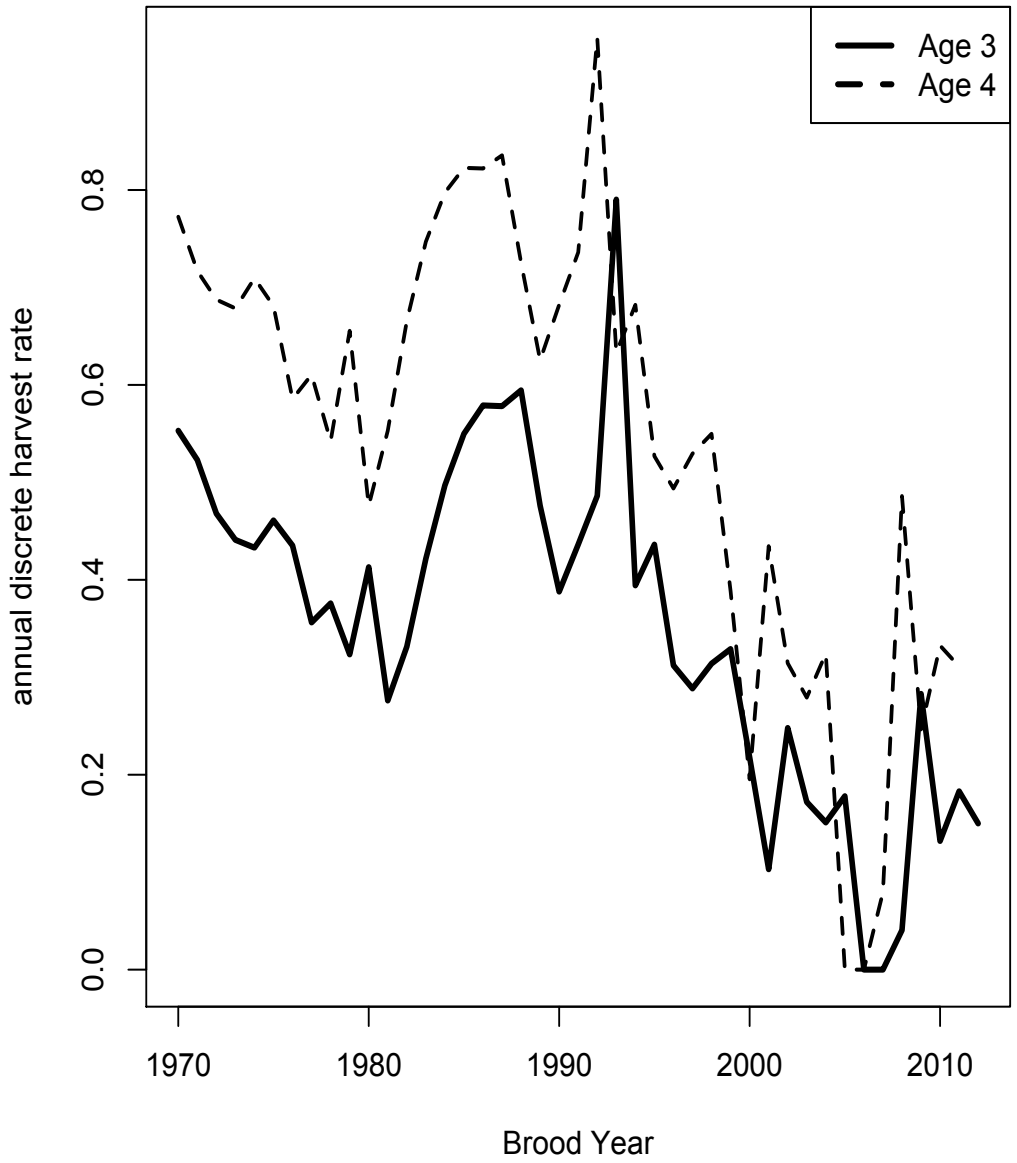
Where S is the survival in habitat h, in month m, and year y, and ε_y is the annual random effect



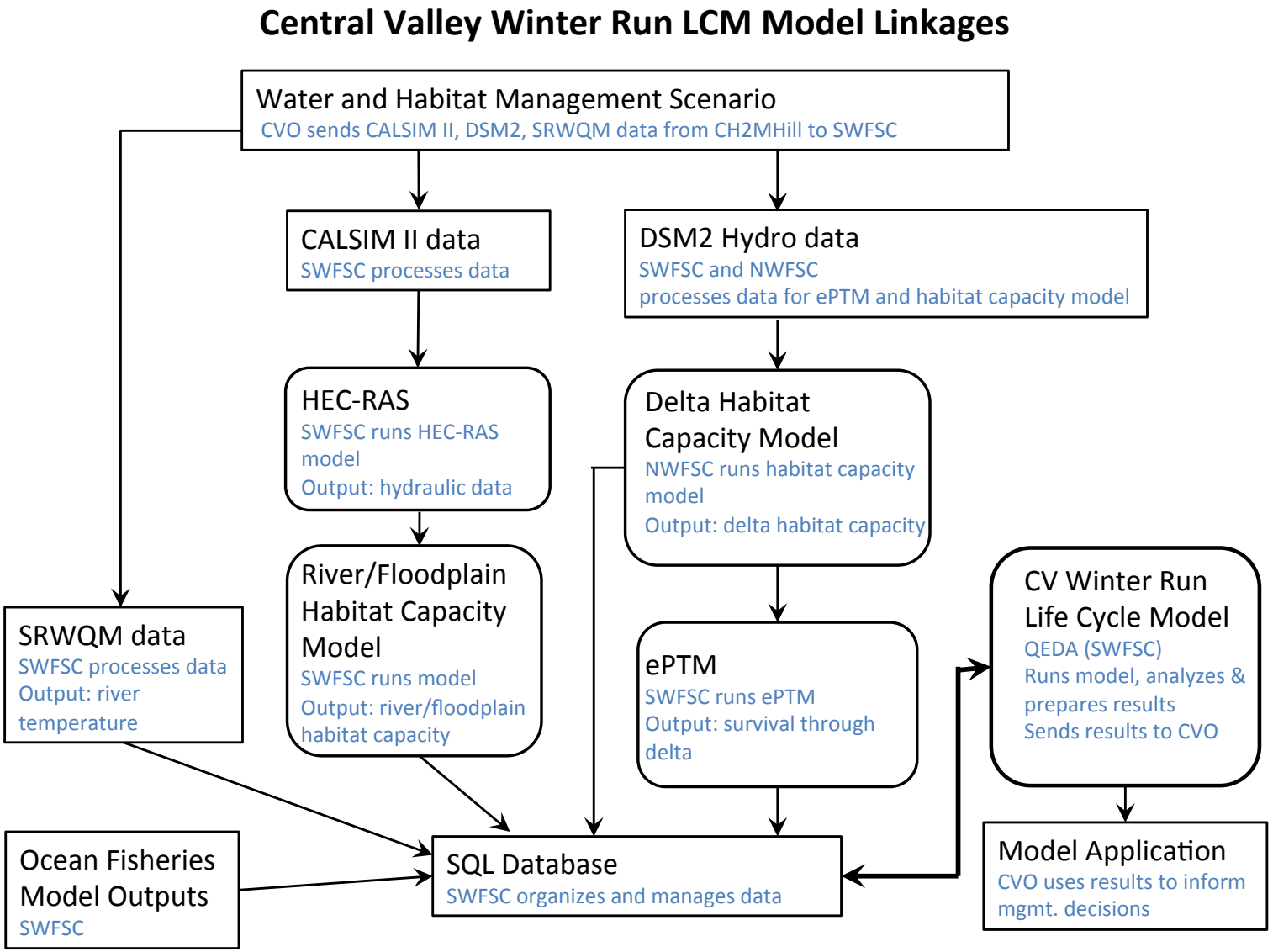
Credit: NOAA

Ocean survival, harvest, maturation

- Age 2 NM: 0.5
- Age 3 NM: 0.8
- Age 4 NM: 0.8
- Age 3 and 4 vulnerable to fishery
- Variable age-3 and age-4 impact historically
- Dominant age 3 maturation ~ 0.9



WRLCM Model Linkages



Physical drivers

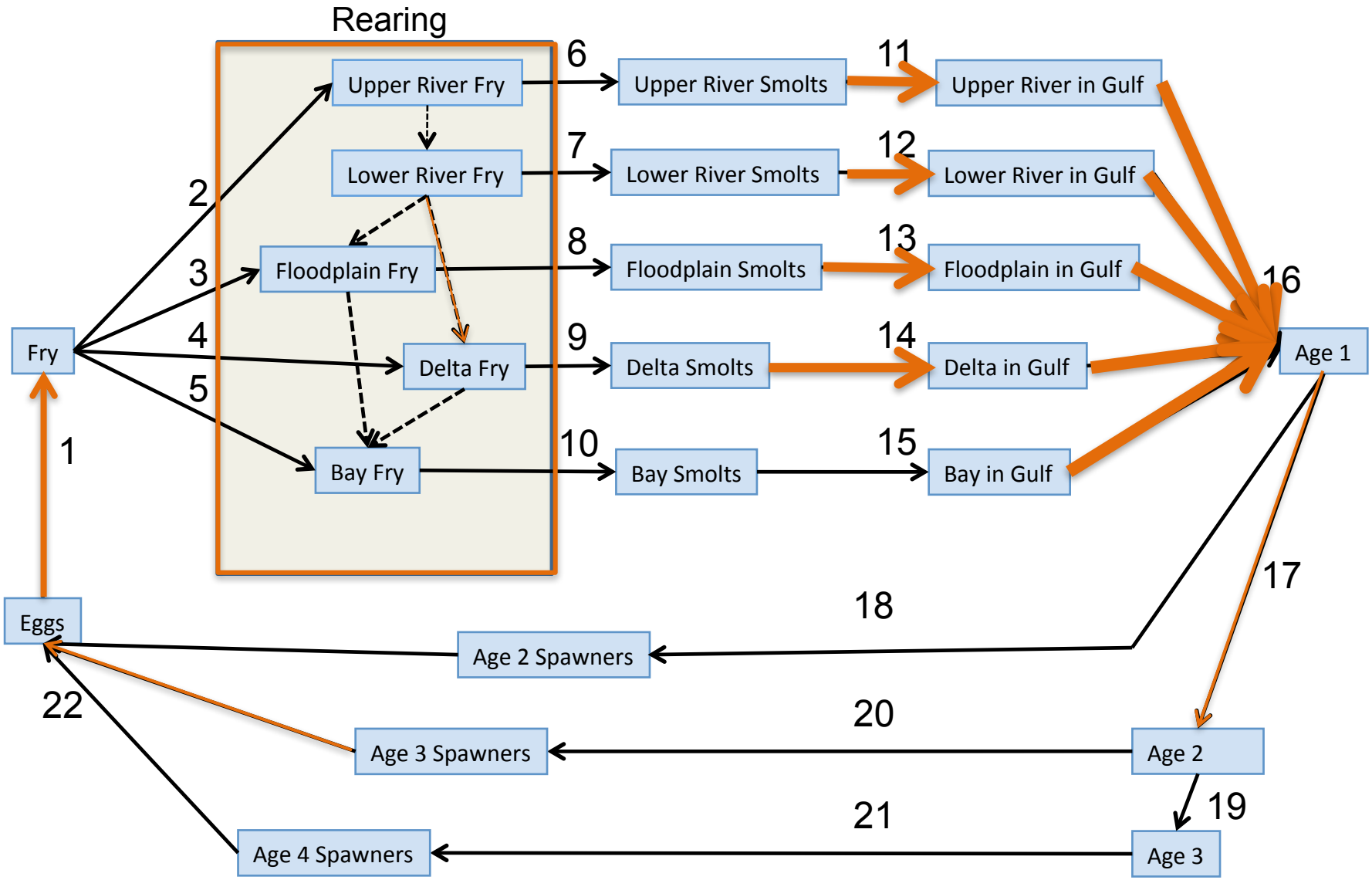
- Temperature at Keswick
  - Egg to Fry Survival (Apr – Oct)
  - Spawn timing (Apr)
- Fremont Weir Spill
  - Yolo entrance probability
- Flow at RBDD
  - Smolt survival
- South Delta Exports
  - Smolt survival
- Flow at Wilkins Slough
  - Movement Lower River to Delta

CALIBRATION

Model fitting (calibration)

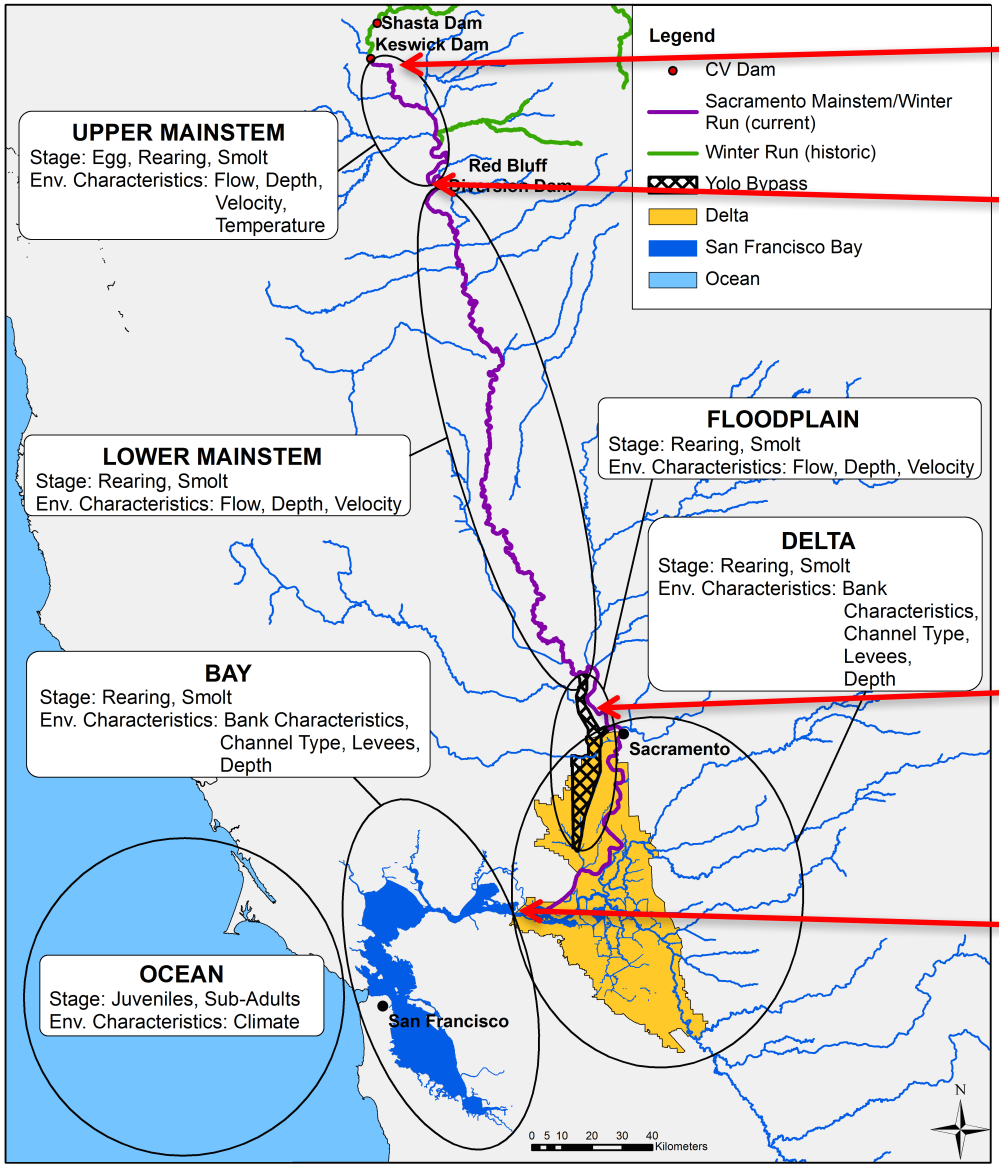
- Potential difficulties with estimation
  - Structurally - not formulated for estimation
  - Parameter space (~ 60 parameters) so a bit over-parameterized
  - Temporal (monthly) and spatial domain (5 regions) are not well represented via survey data
  - Expect identifiability issues and high correlations among parameters
  - Estimate annual random effects and process noise distribution

Cohort Replacement Rate Sensitivity



WRLCM Calibration

Indices of Abundance



Spawners

Juveniles at RBDD

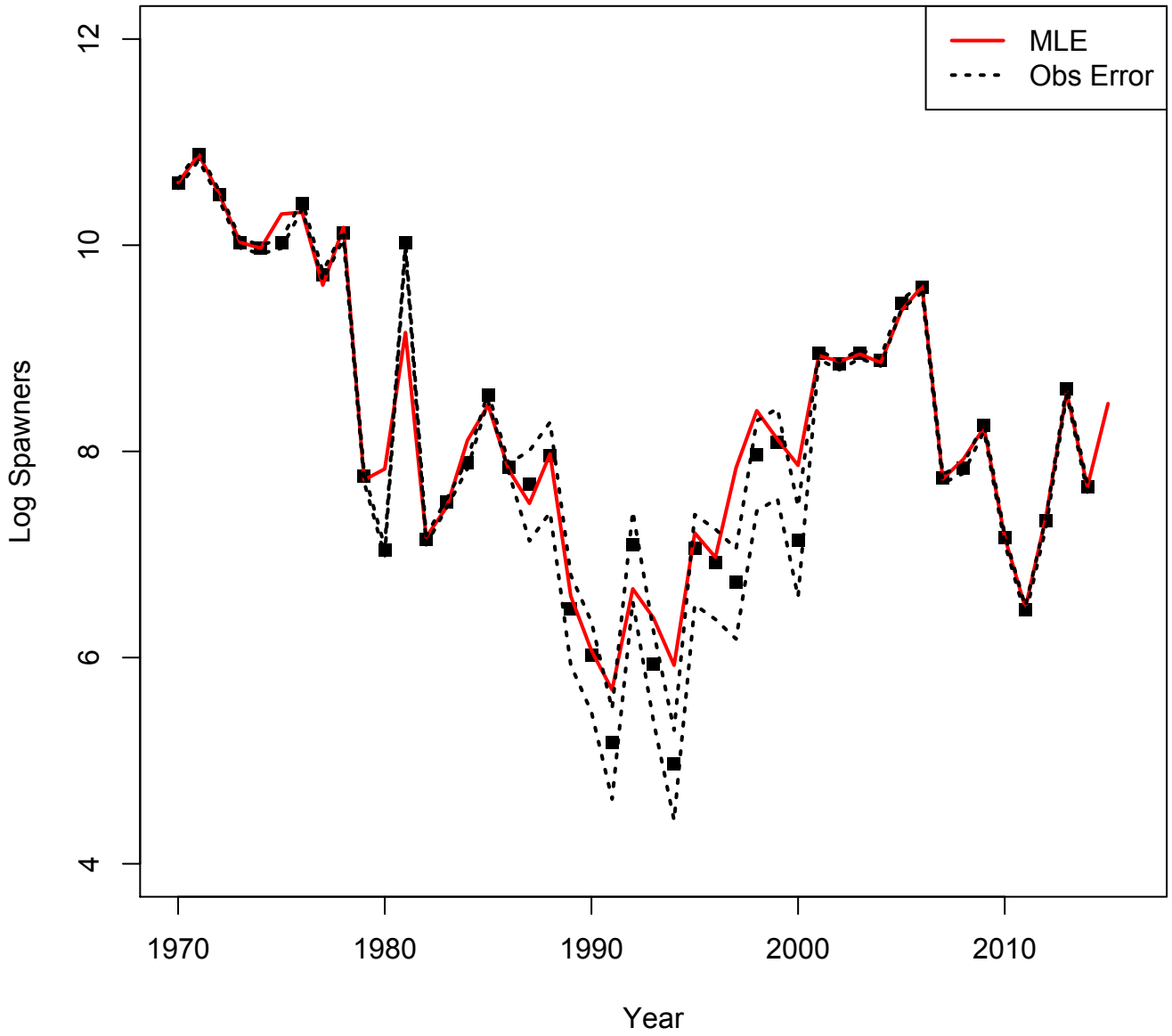
Knights Landing catch

Chipps Island abundance

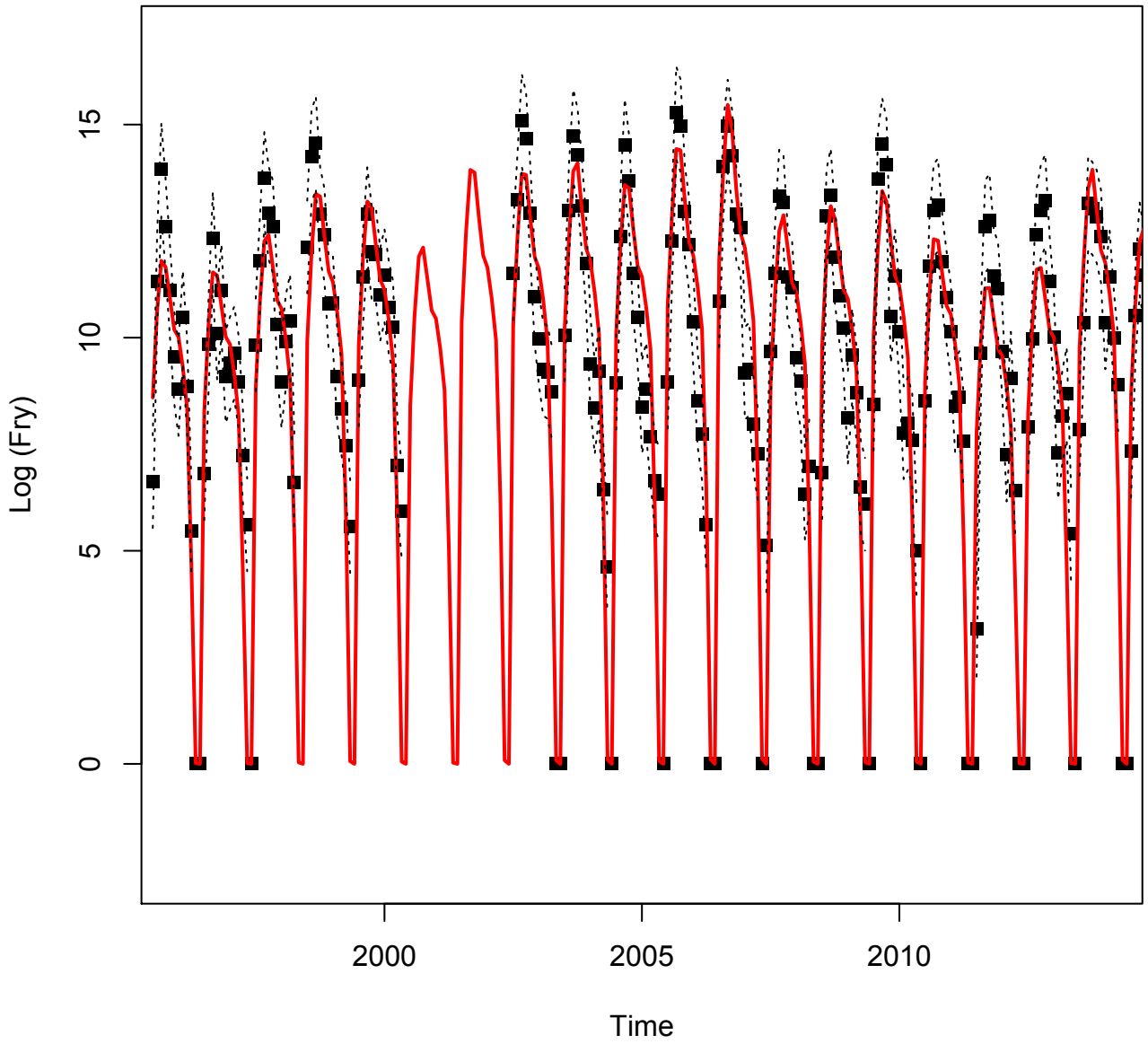
Indices of abundance

Data	Date	Coefficient of Variation	Sampling Distribution	Data time step
Natural Escapement	1970-2014	0.15 (1970-1986) 0.5 (1987-2000) 0.15 (2001-2014)	lognormal	Annual
RBDD monthly juvenile counts	1996-1999, 2002-2014	0.85	lognormal	Monthly
Knights Landing monthly catches	1999 - 2008	NA	multinomial	Monthly
Chipps Island monthly juvenile abundance	2008 - 2011	1.5	lognormal	Monthly

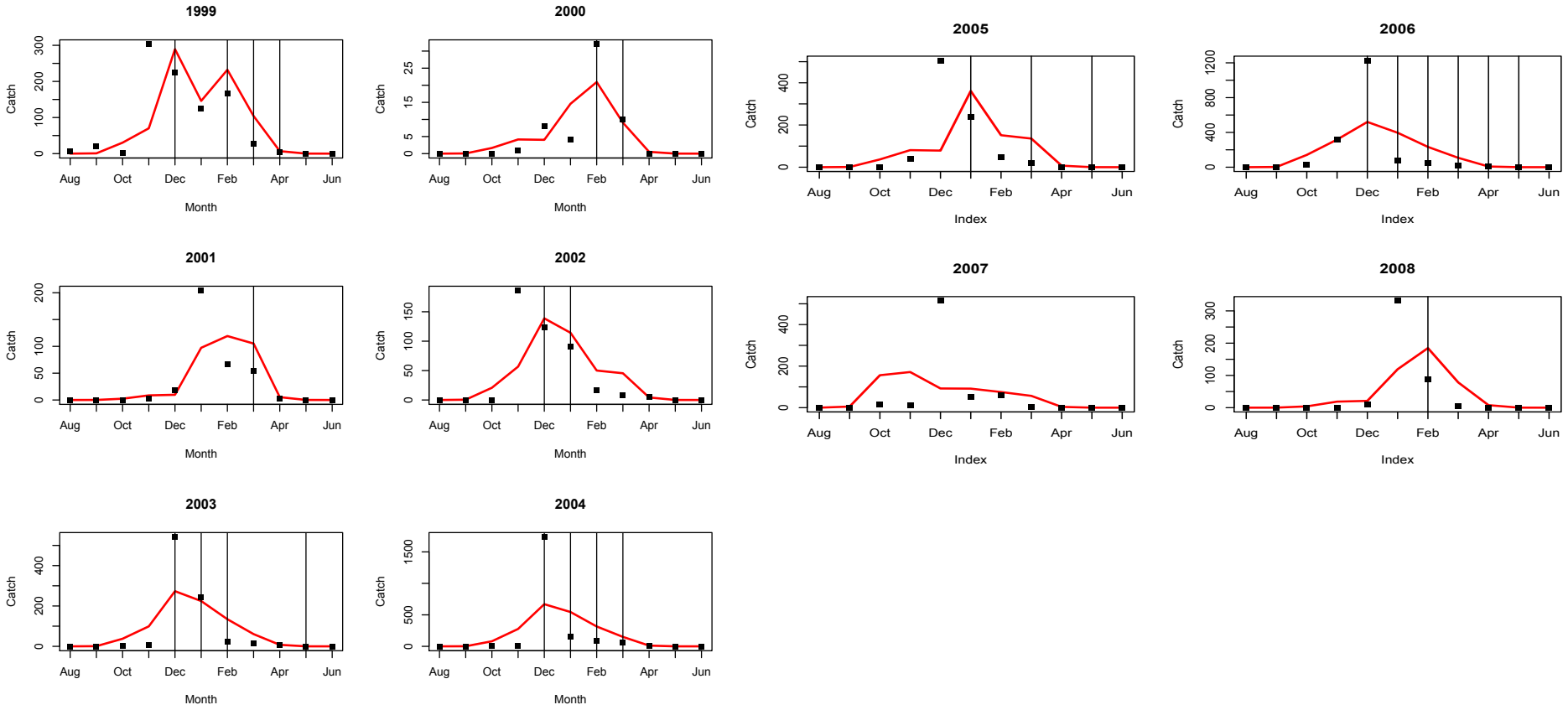
Natural origin log spawners



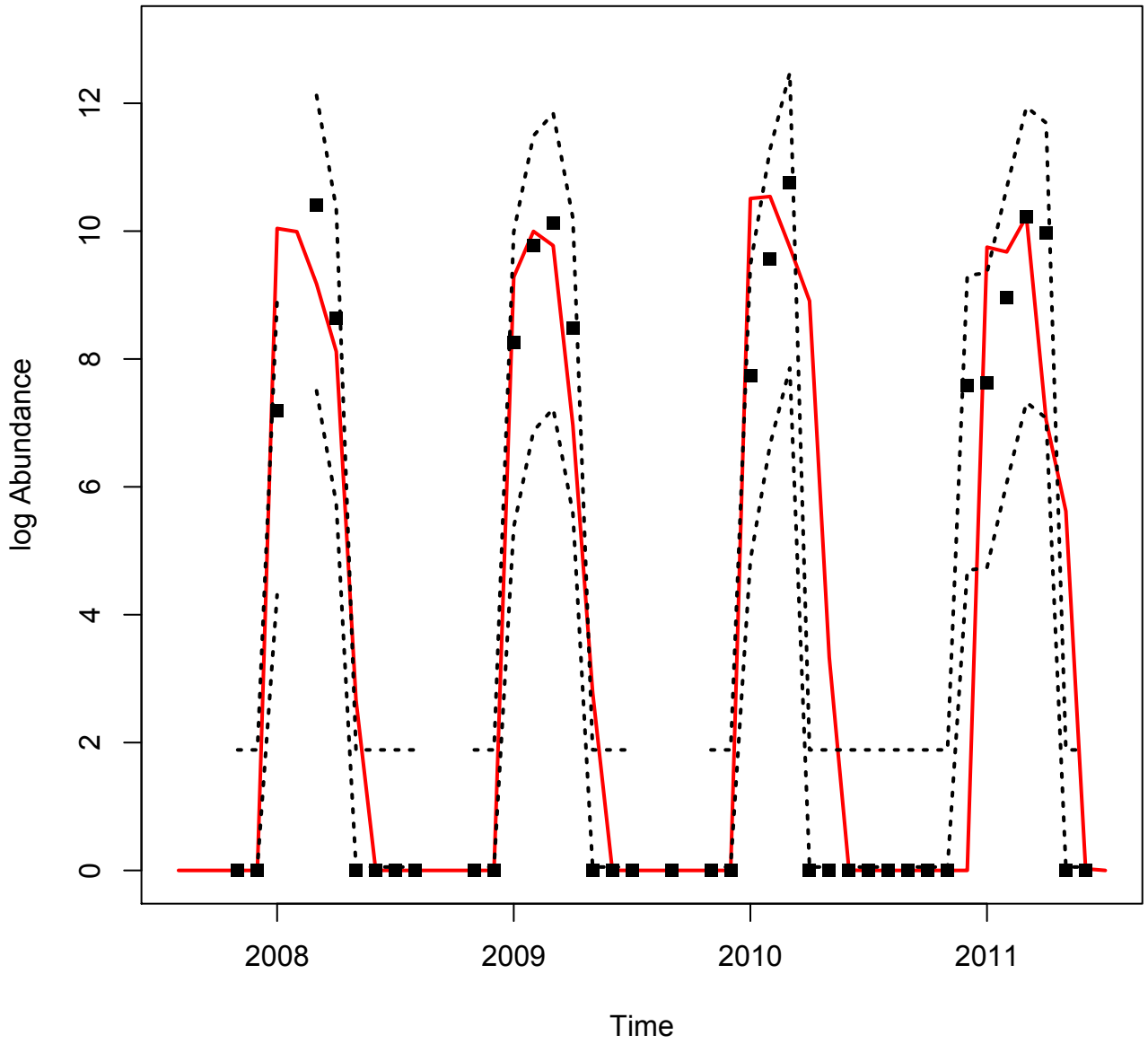
Monthly juvenile log abundance



Knights Landing catch



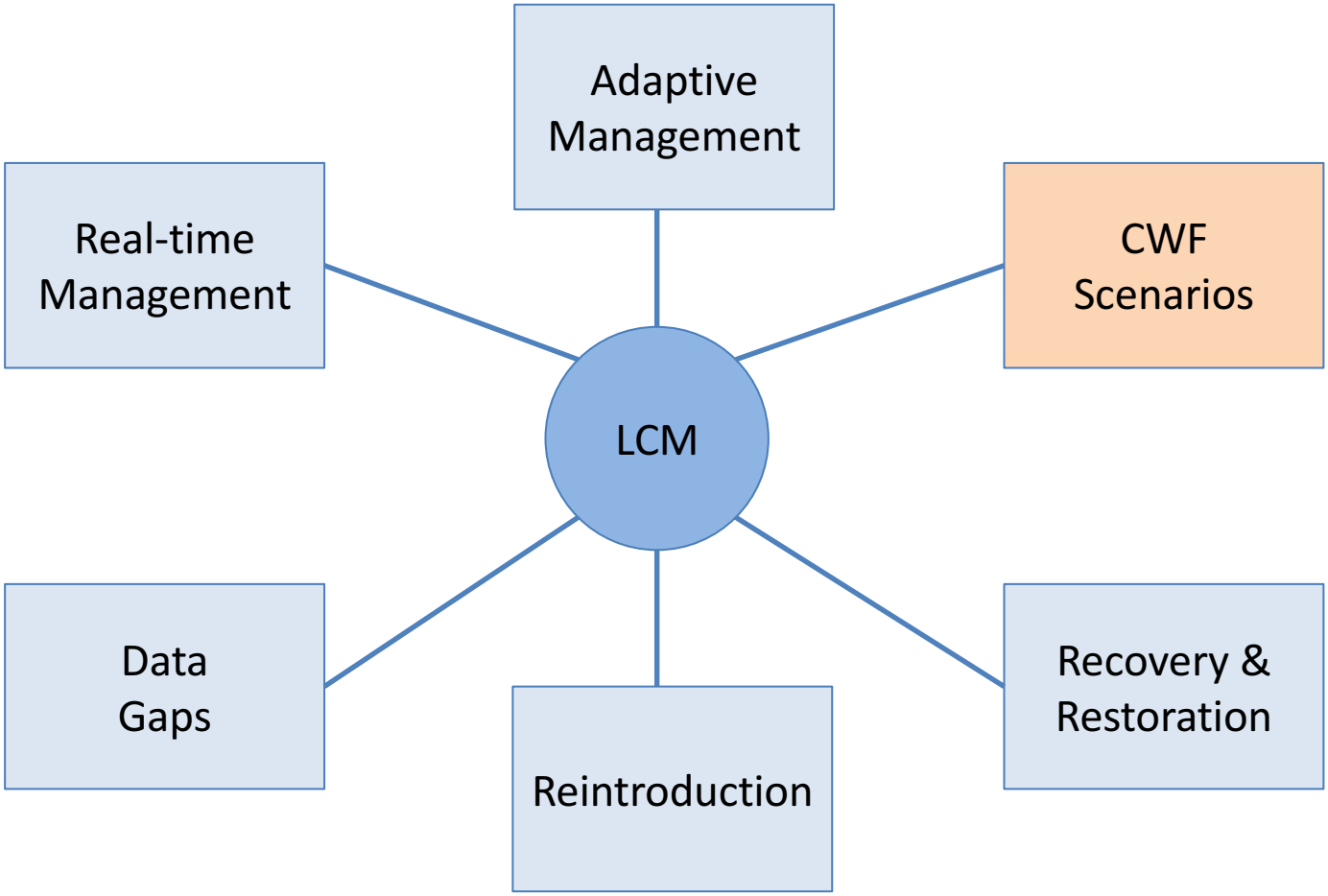
Chipps Island log abundance



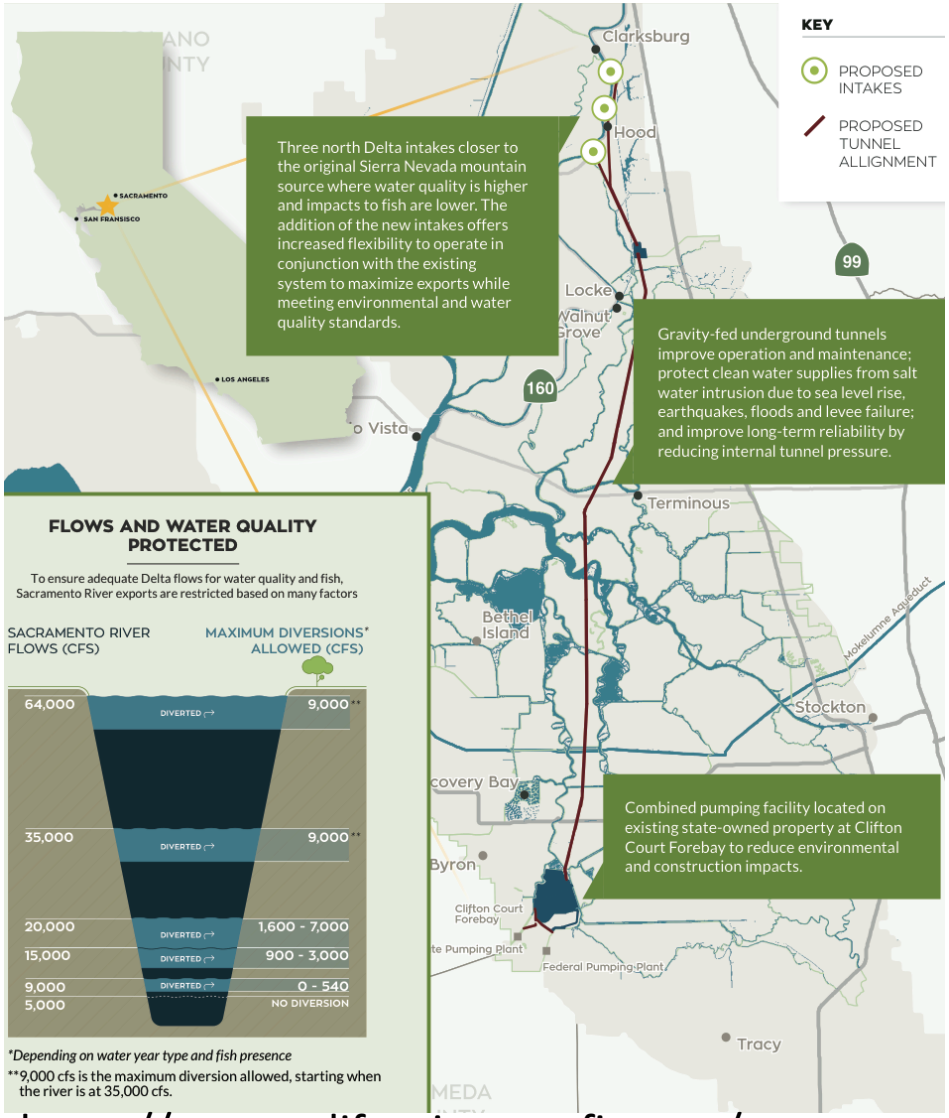
Inference from statistical fitting (Calibration)

- Temperature during April can affect spawn timing (higher temperatures lead to later spawning)
- Spatial distribution in rearing is affected by physical drivers and density dependence
  - Movement out of Lower Sacramento due to flow pulse at Wilkins Slough > 400 m^3s^{-1}
  - Movement to Delta also occurs under higher fry abundance
- ePTM results support Delta as poor place to smolt relative to Sacramento River or Yolo bypass

What types of decisions do we want to address?



California Water Fix

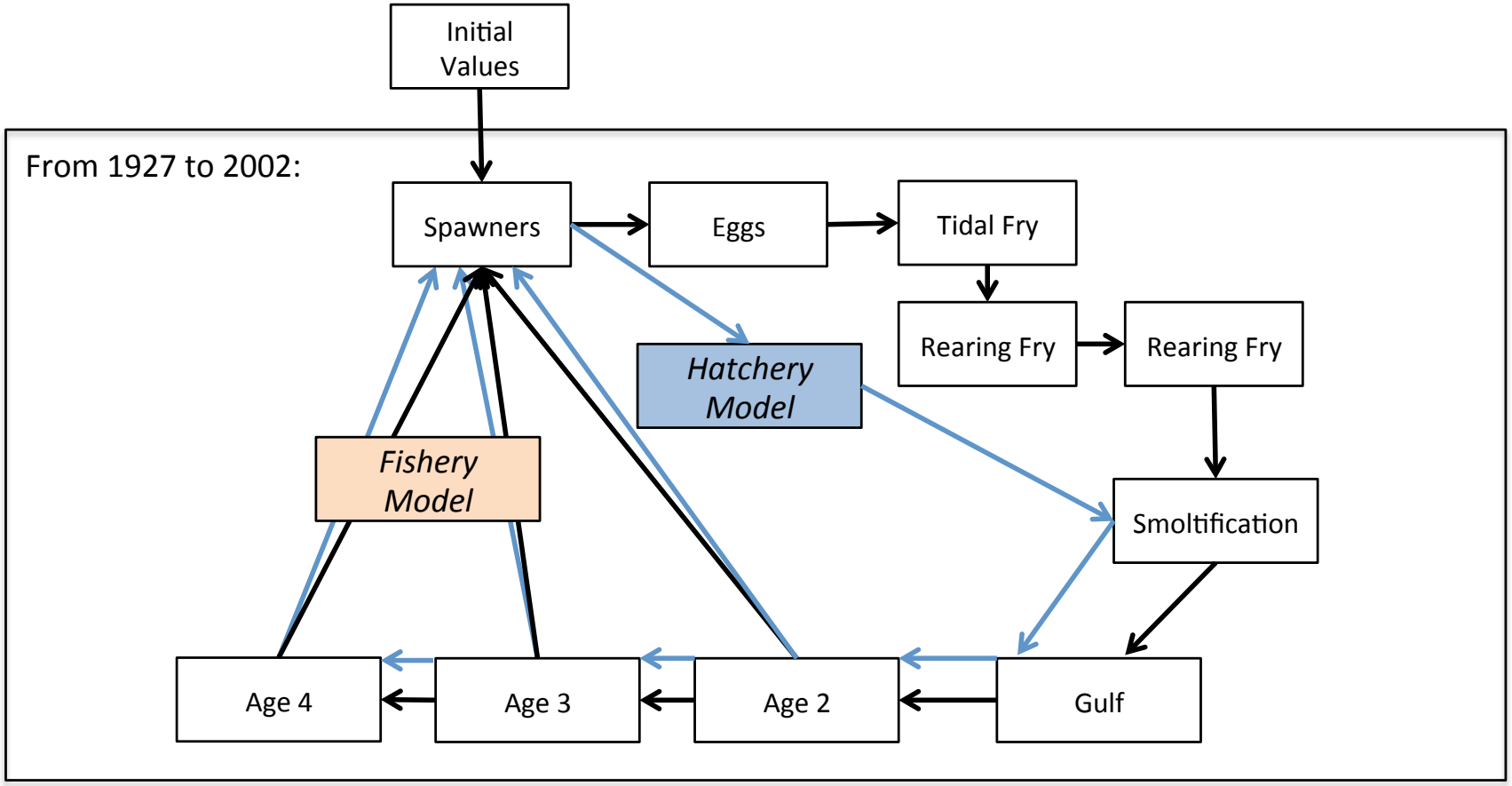


https://www.californiawaterfix.com/resources

- North Delta Diversions (NDD) to provide water to south Delta pumps
- Exports via NDD and/or south Delta depending on water year type

Simulation steps for Cal Water Fix

From 1922 to 1926:

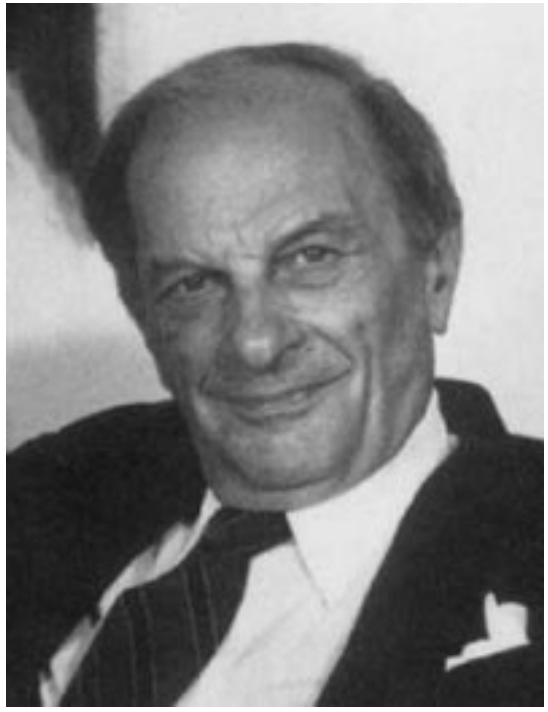


WR LCM Action Evaluations

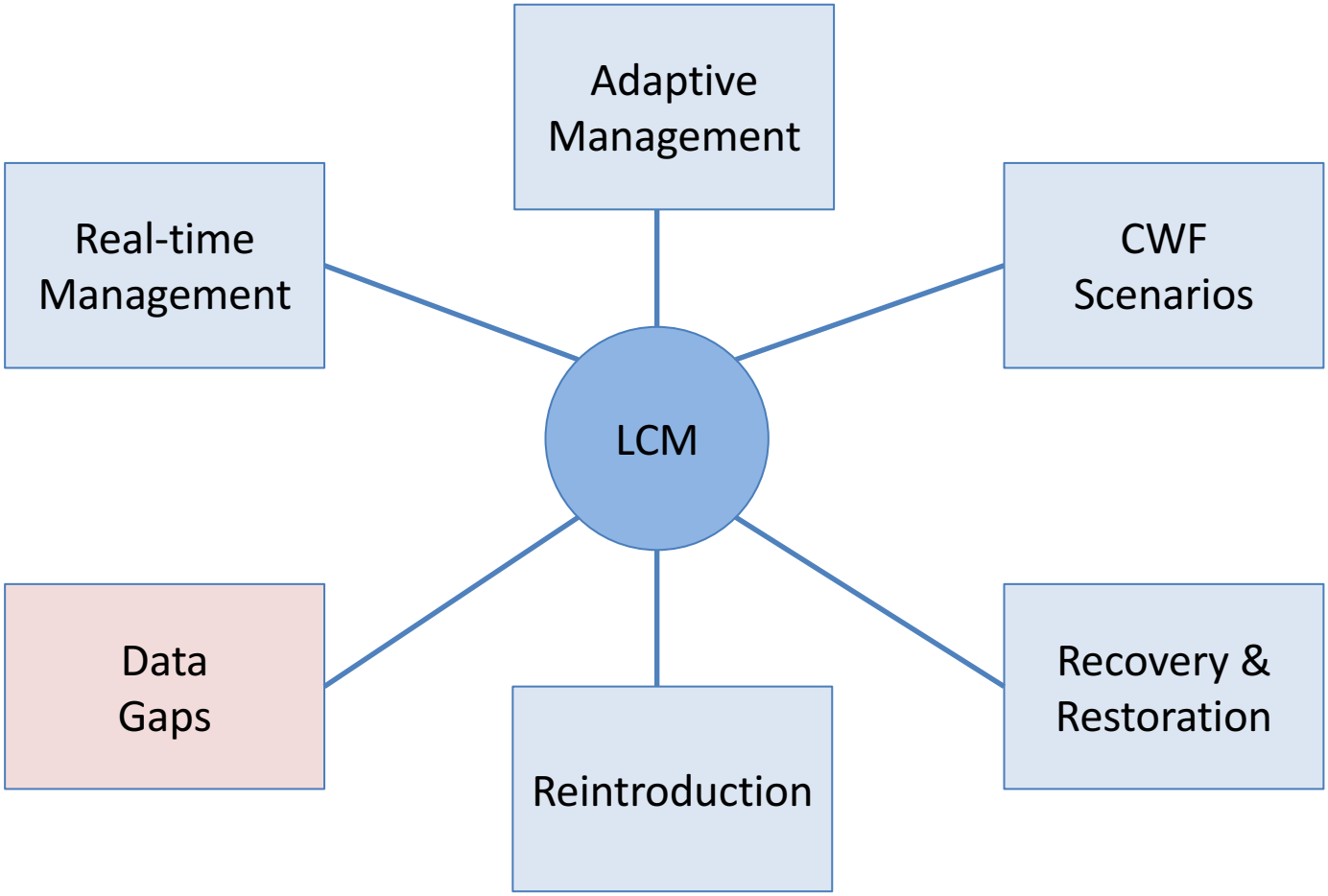
Use Monte Carlo simulation:

1. Run the Base Action under a single ‘state of nature’ or parameter set
2. Run the Alternative action under the same state of nature
3. Calculate relative performance [(Alt – Base)/Base]
4. Repeat over multiple states of nature
5. Summarize relative performance over multiple states of nature

Stanislaw Ulam



Data Limitations

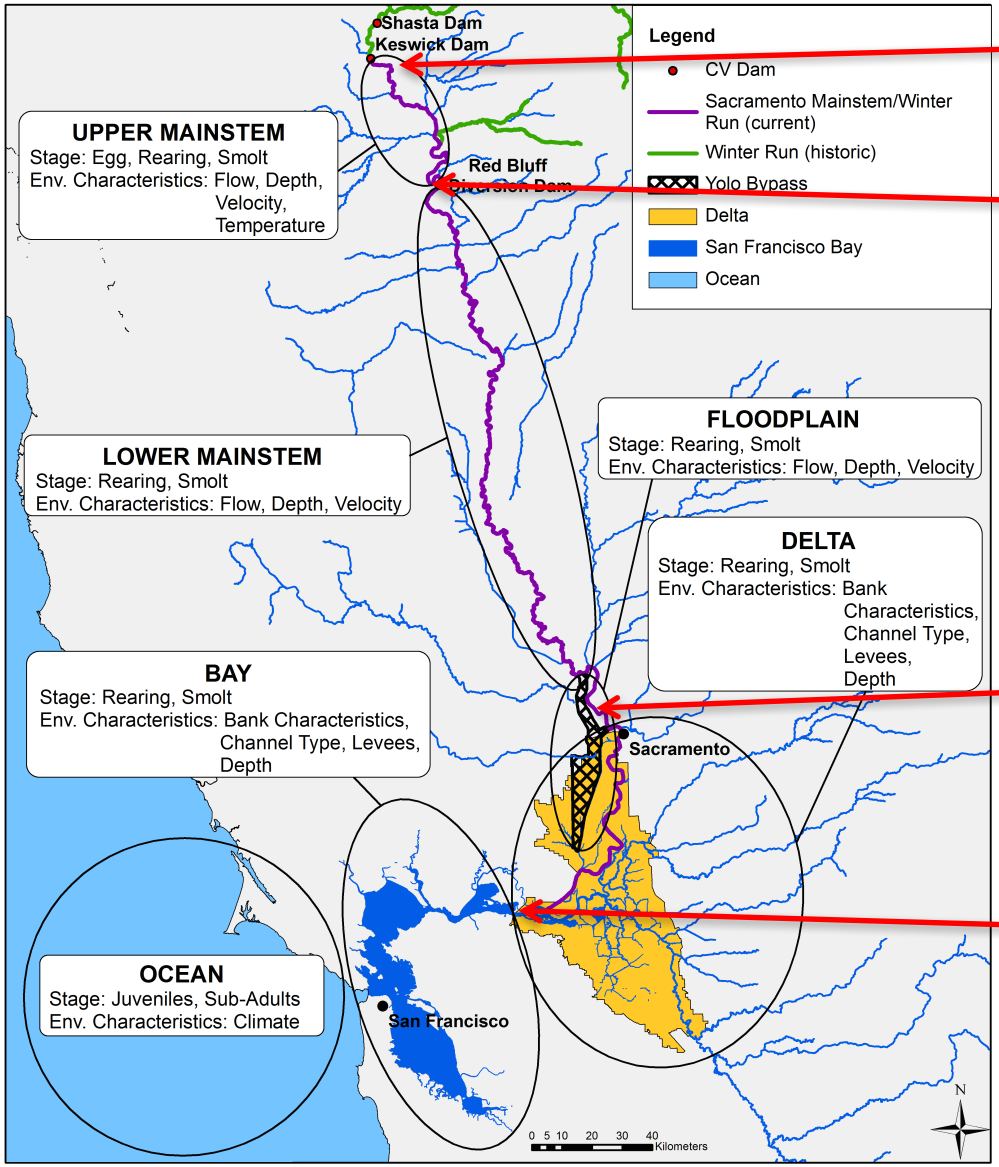


Data limitations

Limitations in available data require making assumptions in the model structure:

- Fry survival is equivalent across all months and habitats
- Timing and proportion of winter run entering the delta are informed by Knights landing catches of WR sized fish
- SAIL recommendations
  - "A robust monitoring network that provides quantitative information about the status of imperiled species at key life stages and geographic locations…"

Evaluate Monitoring



Spawners

Juveniles at RBDD

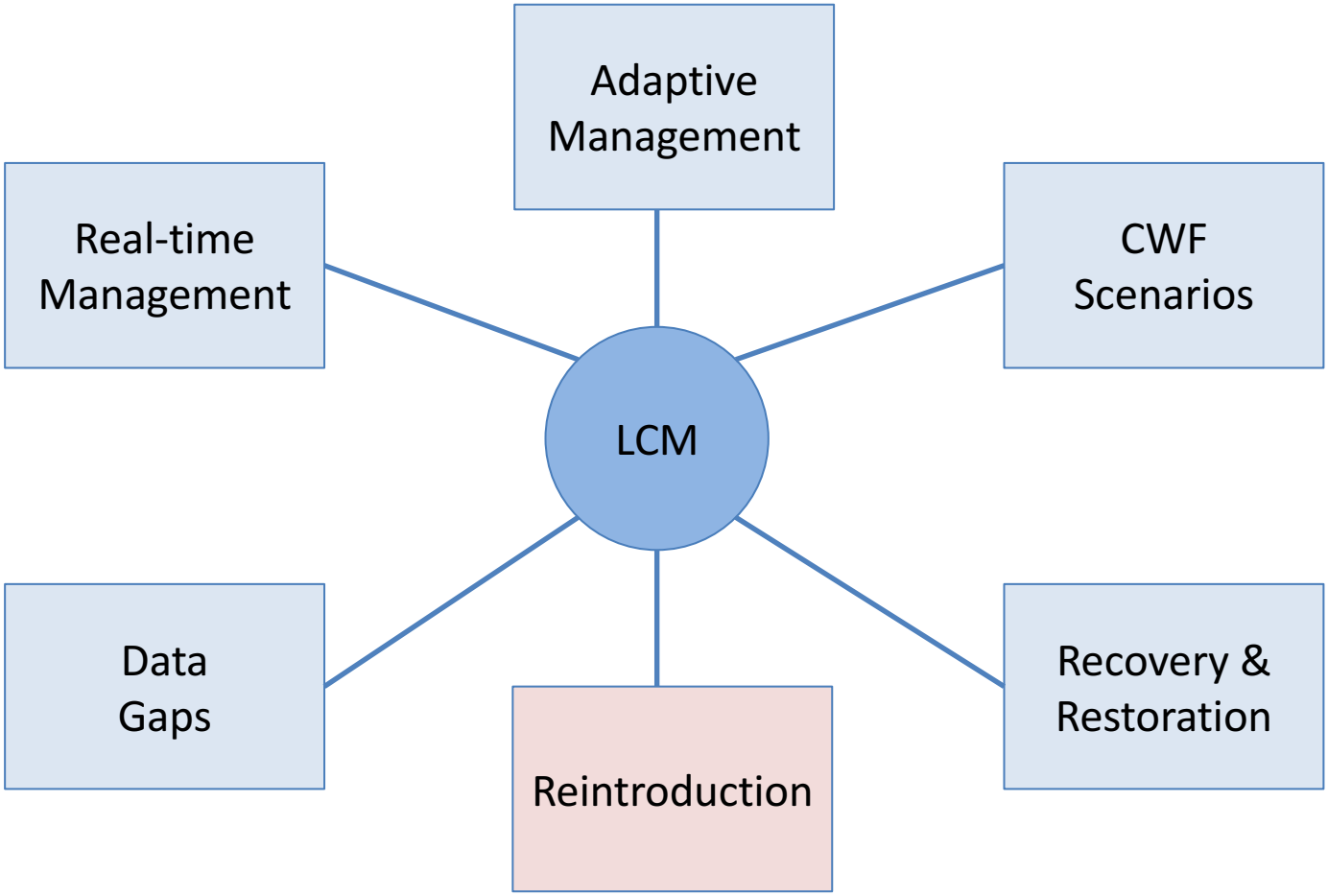
Knights Landing Abundance

Chipps Island abundance

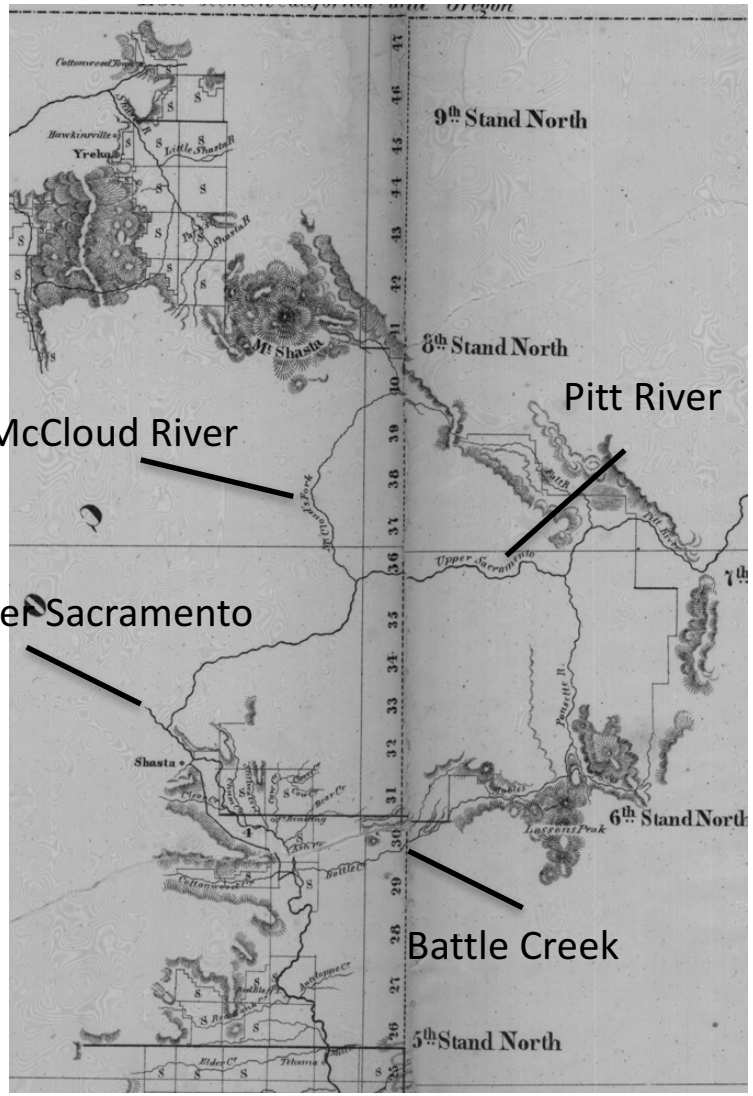
Evaluate Monitoring

- Use of WRLCM for evaluating sampling design to improve understanding
- WRLCM is capable of conducting quantitative assessments of how much uncertainty in survival or movement rates can be reduced for different levels of sampling effort.

What types of decisions do we want to address?



Historical winter-run spawning



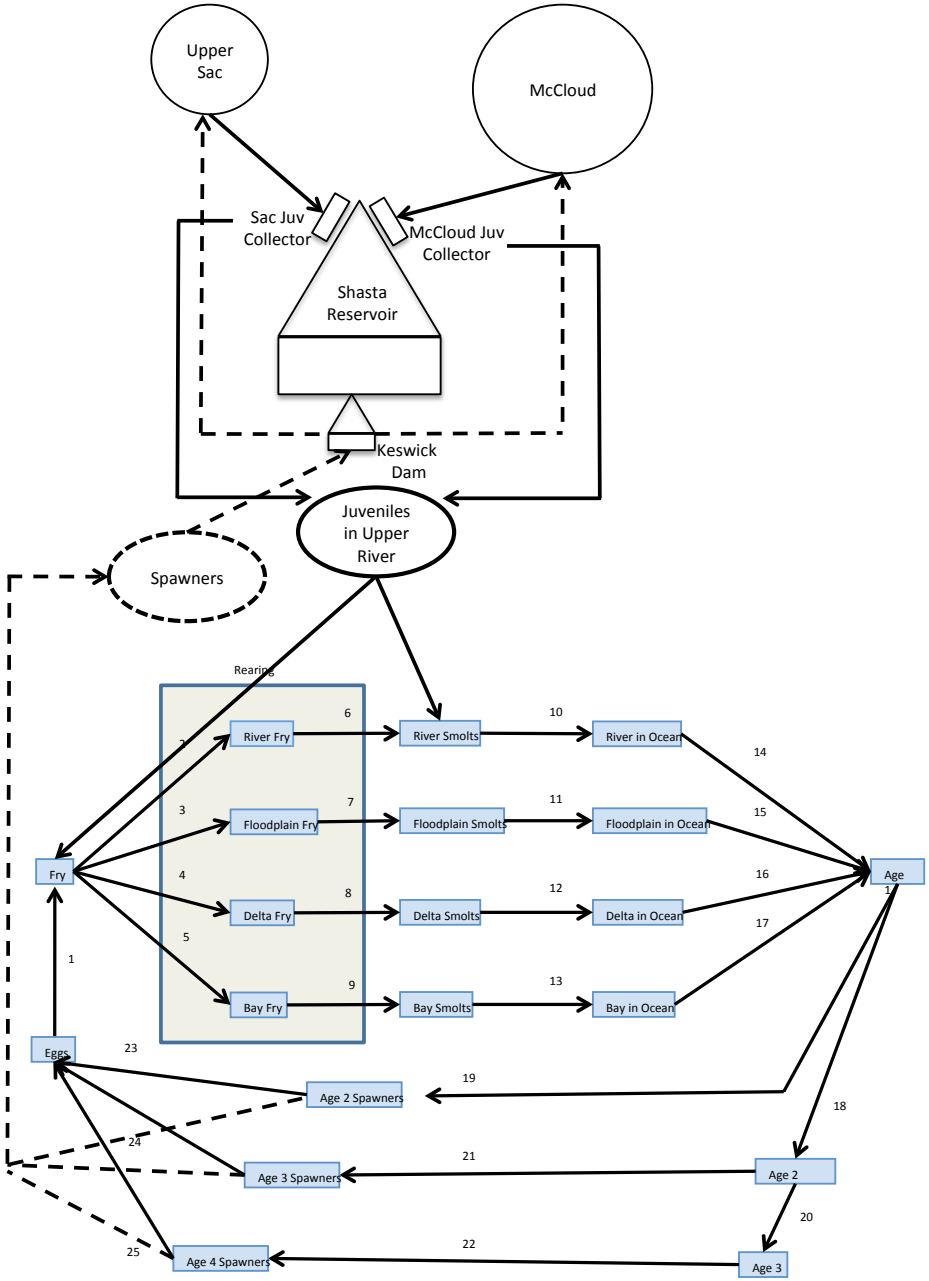
Public survey map in 1856 Williams (2006)

- Historically spawning occurred in the Pitt, McCloud, Hat, Fall, Battle Creeks, and Upper Sacramento River
- Permeable basalt and lava supported cool springs with large, stable flows

Reintroduction Model

Objectives:

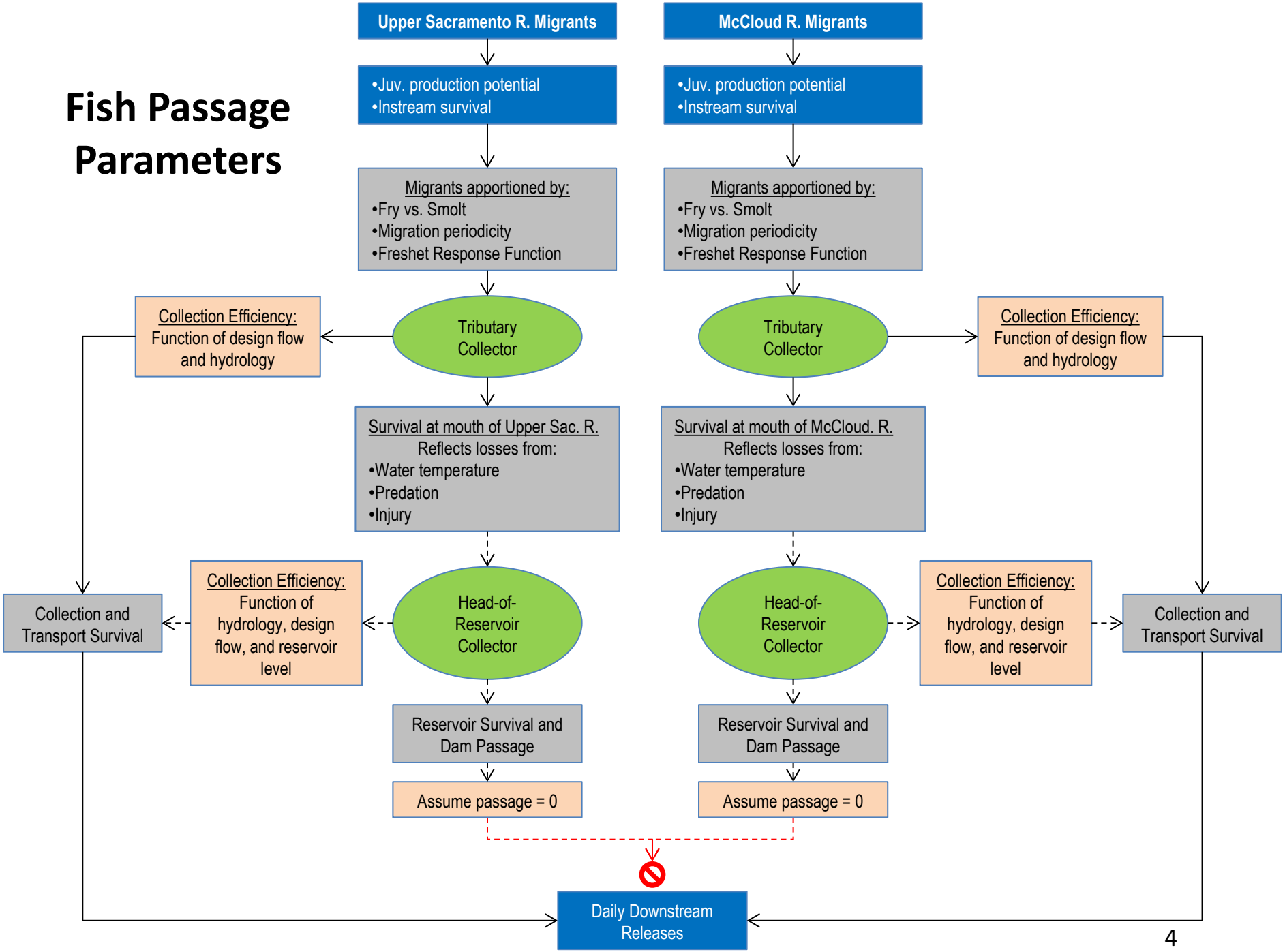
- Link reintroduction to appropriate life cycle stages in the existing life-cycle model
- Develop estimates of fish passage collection efficiency and survival for inclusion in the life cycle model



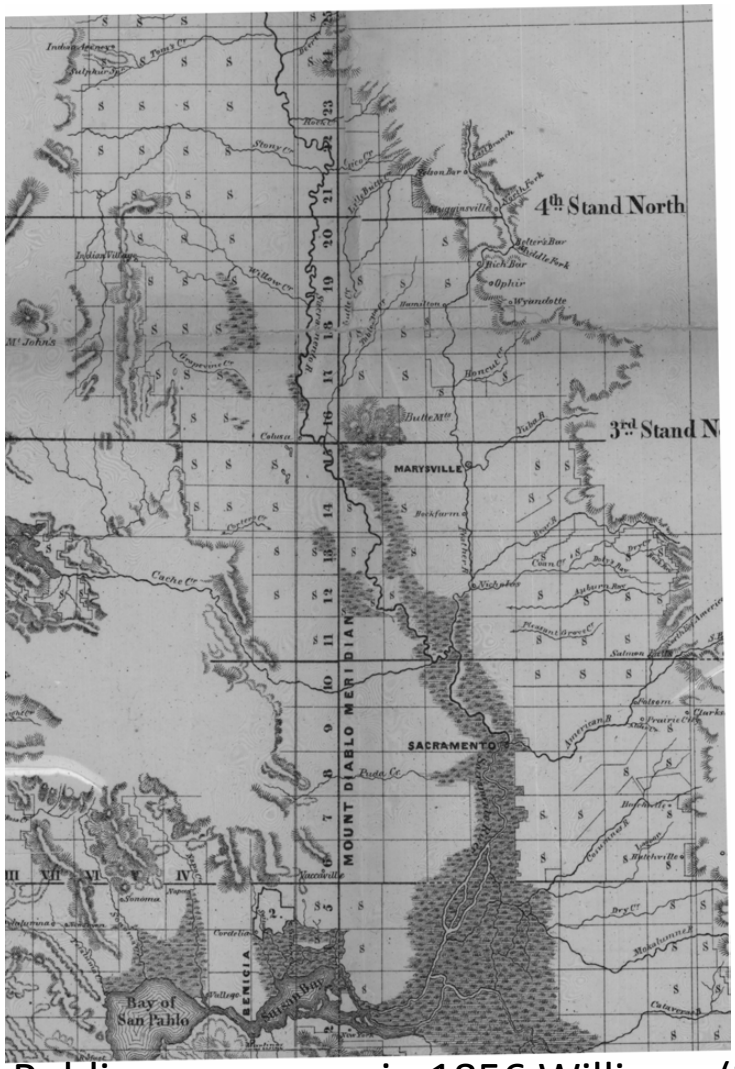
Fish Passage Parameters

- Upper Sacramento River and McCloud River migrants
- Fry and pre-smolt/smolt periodicity
- Migration influenced by flow, freshets, and temperature
- Tributary Collector and Head-of-Reservoir Collector
- Collection efficiency versus hydraulic capacity of facility
- Estimated survival reflecting predation and water temp
- Upstream and downstream passage
- Integrate factors to estimate Percent Passage

Fish Passage Parameters



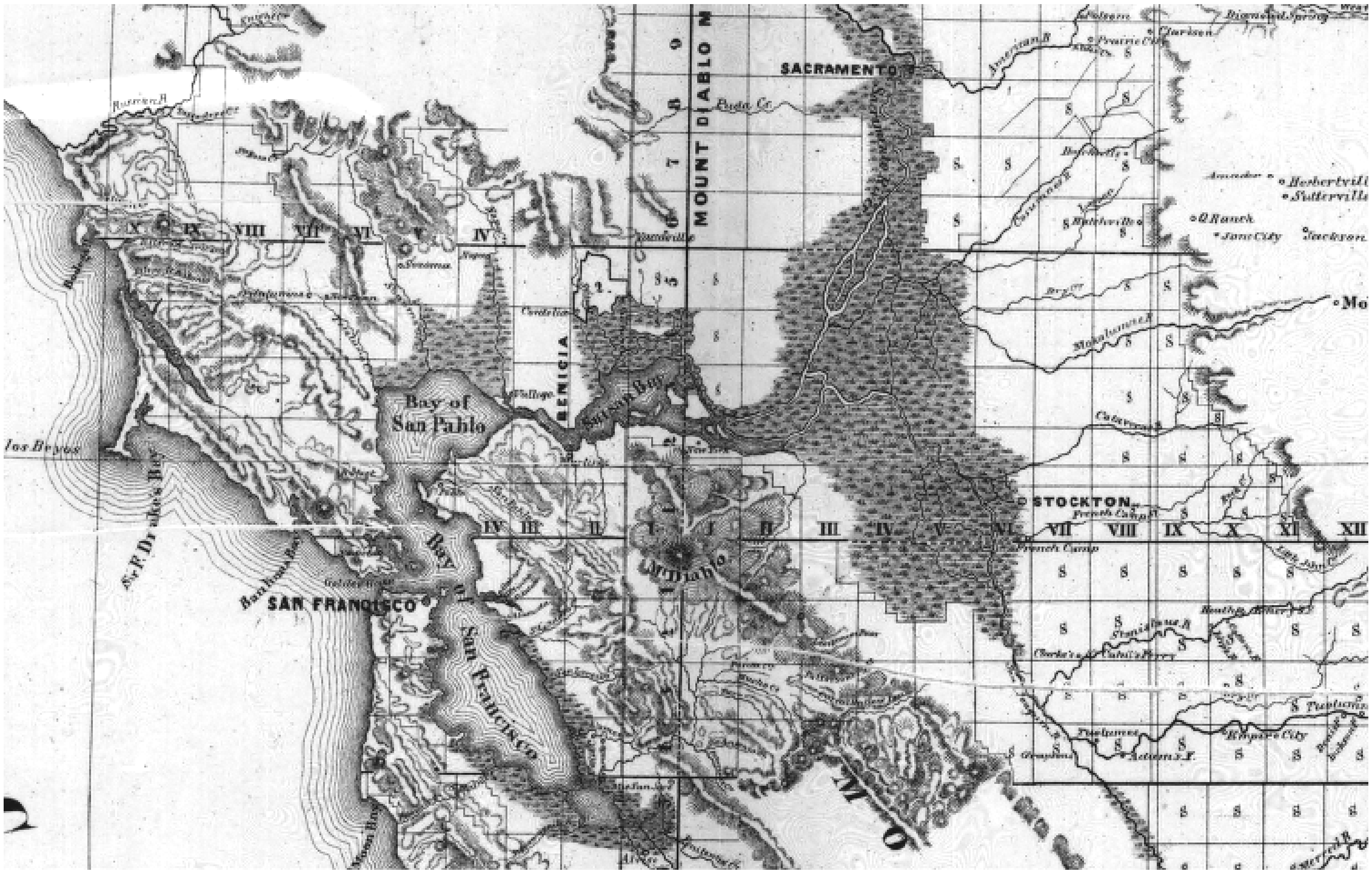
Sacramento Valley



Public survey map in 1856 Williams (2006)

- Extensive wetlands around Sacramento River and northern delta
- Grids are townships (93km^2 or 36mi^2)

San Francisco Estuary

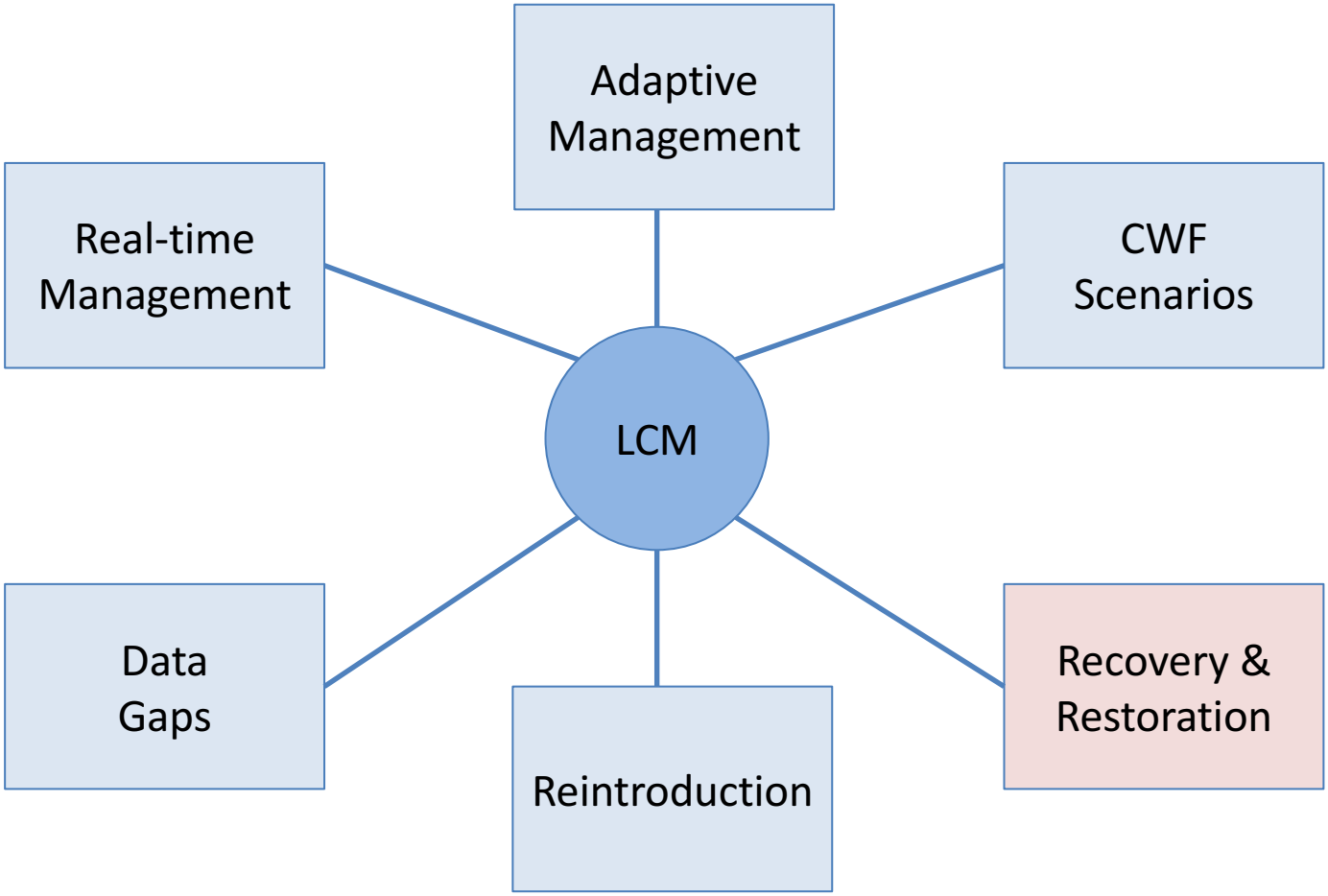


Public survey map in 1856 Williams (2006)

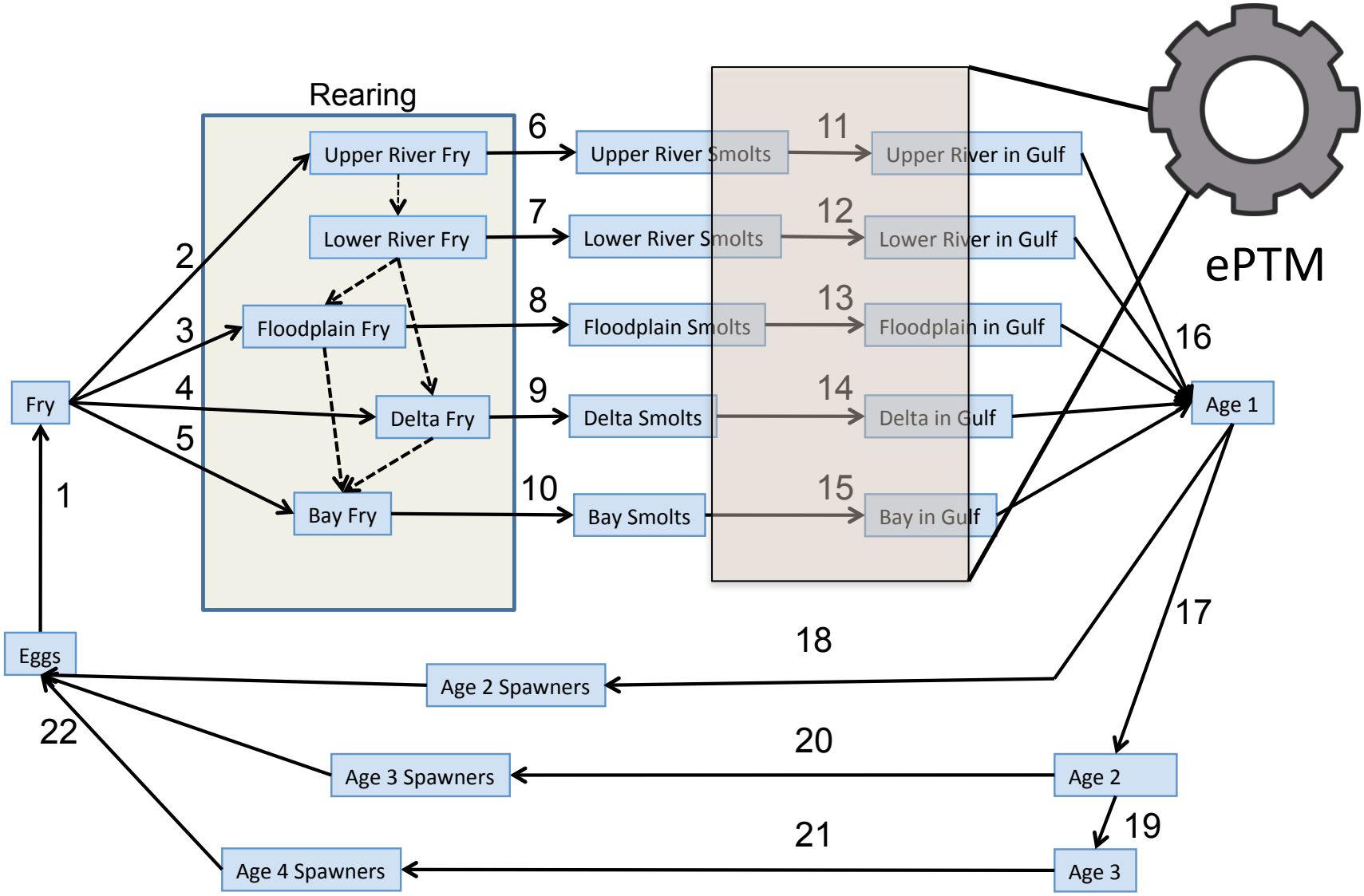
Multi-population WRLCM

- Reintroduction is a special type of additional population segment requiring capture and transport
  - These can be reparameterized to reflect volitional passage
- Also programmed additional population segments, e.g., Battle Creek, for inclusion into the WRLCM
- Working to use WRCLM to represent an 1860's condition

What types of decisions do we want to address?



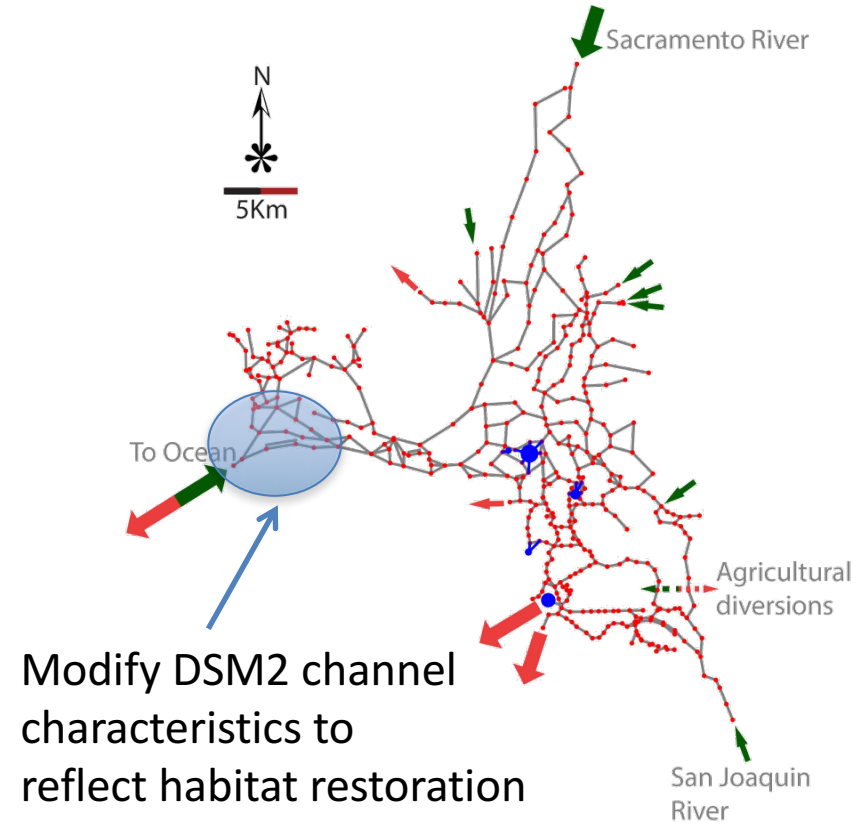
Coupling LCM with ePTM



Tidal Restoration Analysis

Coupled ePTM and LCM modeling

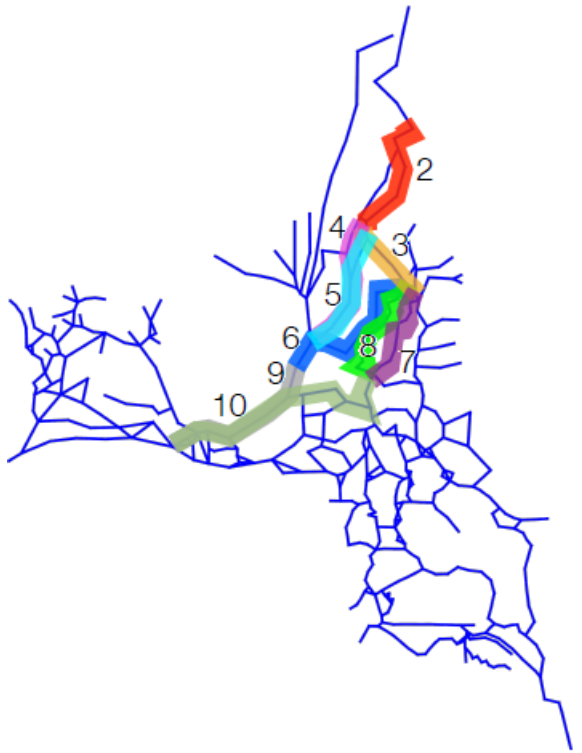
- Evaluate a restoration scenario to reduce tidal amplitude in the delta
- Modify channel characteristics to reflect restoration
- Run ePTM
- Run LCM



Predator management

Coupled ePTM and LCM modeling

- Evaluate a scenario to reduce predation rate
- Modify reach-specific predatory density in ePTM
- Run ePTM
- Run WRLCM



Altering the reach-specific survival probability to reflect changes In predator densities

Next Steps – summer projects

- Calibrate the reintroduction to derive collection and survival performance metrics
- Revisit the estimation methods
  - Objective is forecasting
  - Want to free up some of the fixed parameters
  - Have already developed priors for parameters, so can implement MCMC and variants (MCEM)
- Workshops!

Thank you!

Credit: Steve Culberson